International Journal On Engineering Technology and Sciences – IJETS
ISSN (P):2349-3968, ISSN (O): 2349-3976 Volume XI - Issue II, February – 2024

STRENGTH AND DURABILITY PERFORMANCE OF DOUBLE BLENDED SELF COMPACTING CONCRETE

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ABSTRACT: The basis of human development is socio-economic development. Industrial growth benefits society, whereas it pollutes the environment with garbage. Waste disposal pollutes the land and indirectly pollutes the water, making it poisonous. Most industrial operations produce both beneficial and detrimental pollutants along with waste products. The construction industry is also a significant polluter, accounting for 4% of particle emissions, enhancing water and noise pollution. Particularly in the cement industries, when the calcium carbonate is heated to a very high temperature for the production of lime, the carbon dioxide (CO_2) is released, which contributes directly to greenhouse gases. On the other hand, the industry also uses non-renewable energy sources like fossil fuels for manufacturing of products. When concrete is manufactured with less energy consumption, it will be a sustainable material. Apart from this, to be a sustainable material it must be made of recyclable and eco-friendly materials.

INTRODUCTION

Self-Compacting Concrete (SCC) was first introduced to the concrete industry by Okamura & Ouchi (1995) in the 1980s. SCC was created to address the shortage of unskilled labour in the Japanese construction sector. Many challenges were faced in the compaction process when pouring ordinary concrete in congested reinforcements. Self-Compacting Concrete was created to overcome this problem. Self-Compacting Concrete is one of the special concrete. It can compact by itself under the action of gravity or by its self -weight without vibration, bleeding, and segregation. SCC has a far higher fluidity without segregation than standard concrete. It can fill every corner of formwork under its weight. The key reasons for the increasing attention in SCC are; the less effort needed to complete the particular casting activities and the reduction in time consumption. SCC effectively covers the reinforcement and takes up the shape of any complicated formwork. SCC is obtained by limiting the water-cement ratio, adding an effective plasticizer, increasing the sand-aggregate ratio, and adding some viscosity modifying agents. The elimination of vibrator usage with a significant decrease of environmental noise loading, in and around the site also results in substantial improvements in the health and safety of the workers. The presence of fine-grained inorganic components in the SCC mix allows for mineral admixtures. Let more research have been carried out with waste products as mineral admixtures in SCC & some have been put into practical applications.

Advantages of using SCC

- Can be placed at a faster rate with no mechanical vibration resulting in savings in placement costs.
- Improved and more uniform architectural surface finish with little to no remedial surface work.
- Ease of filling restricted sections and hard to reach areas.
- Structural and architectural shapes and surface finishes not achievable with conventional concrete.
- Improved consolidation around reinforcement and bond with reinforcement.
- Improved pump ability.
- Improved uniformity of in-place concrete by eliminating variable operator related effort of consolidation.
- Less labour
- Shorter construction periods and resulting cost savings.
- Quicker concrete truck turnaround times enabling the producer to service the project more efficiently.

- Reduction or elimination of vibrator noise potentially increasing construction hours in urban areas.

- Minimizes movement of ready mix trucks and pumps during placement.

Influence of fly ash in SCC

The incorporation of fly ash in concrete has gained considerable attention in the construction industry due to its potential to enhance both the performance and sustainability of concrete structures. Fly ash, a byproduct of coal combustion in power plants, is rich in fine particles and possesses pozzolanic properties. When used as a supplementary cementitious material in concrete, it contributes to several positive influences.

One significant advantage of incorporating fly ash is the improvement in the long-term strength and durability of concrete. The pozzolanic reaction between fly ash and calcium hydroxide produced during cement hydration results in additional binding material, leading to denser and more impermeable concrete. This enhances the resistance of the concrete to chemical attacks, such as those caused by sulfates and acids, and reduces the risk of corrosion of reinforcing steel. Moreover, the use of fly ash helps mitigate the environmental impact of concrete production. By substituting a portion of cement with fly ash, the overall carbon footprint of concrete is reduced, as the production of fly ash typically requires less energy compared to the production of cement. This aligns with the growing emphasis on sustainable construction practices and the reduction of greenhouse gas emissions. Fly ash also contributes to workability and pumpability improvements in fresh concrete, making it easier to handle during construction. This is particularly beneficial in large-scale projects where concrete placement efficiency is crucial. Additionally, the use of fly ash can lead to cost savings, as it is often more economical than cement.

However, it is essential to carefully consider the specific characteristics of the fly ash being used, as variations in composition can influence its performance in concrete. Quality control measures must be implemented to ensure consistent results and compliance with industry standards. the incorporation of fly ash in concrete offers a range of benefits, including enhanced strength and durability, environmental sustainability, improved workability, and potential cost savings. As the construction industry continues to prioritize sustainability and performance, the utilization of fly ash in concrete mixtures is likely to become even more prevalent.

Influence of Silica Fume in SCC

Silica fume was first discovered in Norway in 1947 when the environmental controls started the filtering of the exhaust gases from furnaces. The main portion of these fumes was a finely composed of a high percentage of silicon dioxide. As the pozzolanic reactivity for silicon dioxide was well known, many studies have been done on it .There are over 3000 publications that have been published about silica fume and silica fume concrete Conforming to ASTM C 1240, silica fume can be utilised as material for supplementary cementations to increase the strength and durability.

Silica fume consists of the fine particles with specific surface about six times of cement because its particles are very finer than cement particles. Hence, it has been found that when silica fume mixes with concrete the minute pore spaces decreases. Silica fume is pozzolanic, because it is reactive, like volcanic ash. Its effects are related to the strength, modulus, ductility, sound absorption, vibration damping capacity, abrasion resistance, air void content, bonding strength with reinforcing steel, shrinkage, permeability, chemical attack resistance, alkali -silica reactivity reduction, creep rate, corrosion resistance of embedded steel reinforcement, freeze -thaw durability, coefficient of thermal expansion (CTE), specific heat, defect dynamics, thermal conductivity, and dielectric constant.

Need for the study

The production of one metric tonne of cement leads to the emission of one metric tonne of carbon dioxide, which is a powerful greenhouse gas, responsible for the global warming. One way of reducing this environmental problem is to reduce the consumption or production of cement. Since the cement is the basic material which is used in construction industry, it is essential to find a suitable material for the replacement of cement. Conventional method of concrete construction consumes the natural resources like cement, sand, etc. and hence causes ecological imbalance. The use of mineral admixture in concrete construction will save such resources. Faster construction, reduction in site manpower, better surface finish, easier placing, improved durability, reduced noise level and safer working environment are the main advantages of SCC than that of control concrete. At present situation our country needs all these requirements for the safe, clean environment and development. The present investigation on impact strength on SCC is also needed for our construction industry to face the effects of sudden loads on concrete.

Objective of this research work

- To determine the effect of fly ash and silica fume on self-compacting concrete.
- To develop the self-compacting concrete mixes with two pozzolans, fly ash and silica fume in place of cement.
- To evaluate the rheological and mechanical performance of SCC with inclusion of fly ash and silica fume as mineral admixture.
- Formulating suggestions for acceptable SCC combinations based on FA and SF for building applications.

Scope of this research

In order to maintain the equality in the society every individual family must own a house, however, at an affordable cost. Nowadays due to the price hike of building materials, owning a house is still a dream to the poor one. Many industrial wastes and byproducts which possess cementitious properties are cheaper in cost. They can be used to meet out the requirements of the poor. By doing so the pollution created by dumping of industrial wastes near surrounding locations was decreased. Because of the increased population in urban areas the construction of high rise buildings with congested reinforcements is unavoidable. Hence suitable construction techniques and materials must be followed and used to enhance the quality of the structure. One of the best techniques to be used in congested reinforcement areas is SCC, but the SCC in these areas requires error-free compaction and densely packed concrete. The solution for this problem may be achieved by the use of industrial waste as a filler and admixture in SCC.

LITERATURE REVIEW

A literature study that reviews pertaining to the enhancing effects of double blended mineral admixtures. To enhance specific characteristics of self-compacting concrete (SSC). This chapter focuses on gathering diverse data and findings from journals, websites, and other sources relating to the behavioural analysis of Self Compacting Concrete (SCC) with the impact of cementitious ingredients.

Vikas et al. (2013) explored that the use of supplementary cementitous materials is fundamental in developing low cost construction materials for use in developing countries. By addition of some pozzolanic materials, the various properties of concrete viz,workability, durability, strength, resistance to cracks and permeability can be improved. Silica fume is known to improve both the mechanical characteristics and durability of concrete.

Hanumesh, Varun & Harish (2015) study and observes the Mechanical Properties of Concrete Incorporating Silica Fume as Partial Replacement of Cement.The main aim of this work is to study the mechanical properties of M20 grade control concrete and silica fume concrete with different percentages (5, 10, 15 and 20%) of silica fume as a partial replacement of cement. The result showed that The compressive strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in compressive strength and The split tensile strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in split tensile strength.The optimum percentage of replacement of cement by silica fume is 10% for M20 grade of concrete.Shanmugapriya & Uma (2013) carried an Experimental Investigation on Silica Fume as a partial Replacement of Cement in High Performance Concrete.The concrete used in this investigation was proportioned to target a mean strength of 60 MPa and designed as per A The water cement ratio (W/C) adopted was 0.32 and the Super Plasticizer used was CONPLAST SP 430.Specimens such as cubes, beams and cylinders were cast for various mix proportions and tested at the age of 7,14and 28 days CI 211.4R-08.The investigation revealed that the partial replacement of cement by silica fume will develop sufficient compressive strength, flexure strength and split tensile strength for construction purposes. The optimum dosage of silica fume found to be 7.5% (by weight), when used as partial replacement of ordinary Portland cement

Bouzouboa & Lachemi (2001) studied the preparation methodology of SCC containing fly ash of Class F in high volumes. The hardened property like compressive strength increased for an increase in the percentage of fly ash used as a cementitious replacement. The study stated that SCC was produced in an economical state using high volume fly ash

Khatib (2008) carried out the assessment on the performance of SCC influenced by fly ash. The fresh properties of concrete were conducted to examine the workability characteristics. The compressive strength resulted in increased strength for increased content of fly ash in concrete. At a certain limit, the increase in fly ash reduced the strength and increased absorption values.

Ghutke and Bhandari (2014) studied and concluded that silica fume should be used as partial replacement of Portland cement . Silica fume is nonmetallic and non-hazardous waste of industries. It is suitable for concrete mix and improves properties of concrete i.e. compressive strength etc. The main objective of this research work is to determine the optimum replacement percentages which can be suitably used under the Indian conditions. To fulfill the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done .It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage (10% replacement of cement by silica fume).But higher replacement of cement by silica fume gives lower strength).

Krishna and Aruna (2013) investigated that the effects of using supplementary cementitious materials in binary and ternary blendson the fresh and hardened properties of Self-Compacting Concrete (SCC). For this purpose, four mixtures were designed and water/Cementitious ratio as 0.36 with 0.9 % of Super plasticizer cum retarder dosage by weight. The controlled designed mix only ordinary Portland cement (SCC) as the binder while the remaining mixtures incorporated binary cementitious blends of OPC and Fly ash (FA).

After mixing, the fresh properties of the SCC were tested for slump flow, V-funnel flow time and L-Box ratio. Moreover, compressive and split tensile strengths of the hardened concrete were measured at 7, 28, 90 and 180 days. Test results have revealed that the compressive strength of the binary and ternary blends of SCC is performed whilst the split tensile strength of the controlled concrete with all binary and ternary concrete for all curing ages.

Elyaman et al. (2014) studied the effect of various filler types on the fresh and hardened properties of self-compacting concrete (SCC) and Flow-able concrete. For this purpose, two groups of fillers were selected. The first group was pozzolanic fillers (silica fume and metakaolin) while the second group was non-pozzolanic fillers (limestone powder, granite dust and marble dust). The test results showed that filler type and content have significant effect on fresh concrete properties where non-pozzolanic fillers improve segregation and bleeding resistance. Generally, filler type and content have significant effect on unit weight water absorption and void ratio. In addition, non pozzolanic fillers have significant effect on unit weight, water absorption and voids ratio. In addition, non-pozzolanic fillers have insignificant negative effect on concrete compressive strength.

Vikas et al. (2013) explored that the use of supplementary cementitous materials is fundamental in developing low cost construction materials for use in developing countries. By addition of some pozzolanic materials, the various properties of concrerte viz, workability, durability, strength, resistance to cracks and permeability can be improved. Silica fume is known to improve both the mechanical characteristics and durability of concrete.

Heba A. Mohamed (2011) presents an experimental study on self-compacting concrete (SCC) with two cement content. The work involves three types of mixes, the first consisted of different percentages of fly ash (FA), the second uses different percentages of silica fume (SF), and the third uses a mixture of FA and SF. After each mix preparation, nine cylinder specimens are cast and cured. Three specimens are cured in water for 28 days, three specimens are cured in water for 7 days, and three specimens are left in air for 28 days. The slump and V-funnel test are carried out on the fresh SCC and concrete compressive strength values are determined. The results show that SCC with 15% of SF gives higher values of compr

Kennouche.S.et.al, (2013) stated that Self-compacting concrete (SCC) was elaborated using local materials and silica fume (SF) as admixture in 15% of cement quantity, two different Portland cements (PC) and two different superplasticizer that the chemical nature is polycarboxylate and plynaphtalene, the aggregates used are (AG 3/8 mm, AG 8/15 mm), coarse and fine sand (SC, SF) witch fineness modulus 3.2 and 1 in the order. The dosage of the different super plasticizer used is chosen after experimental spreading tests of each self-compacting concrete formulation. Results of fresh concrete tests executed, as L-box and segregation resistance are on concordance whit values recommended by the French association of civil engendering. Also the mechanical characterization was conducted by compressive strength and splitting compression testing procedure, results values are in the range higher than 20 Mpa at the seven day by the compressive test for the all compositions, and the highest value was 40.93 MPa at the 28 day bay compressive test of the fourth's formulation specimens, the values of splitting compressive tests of al formulation specimens at 7, 14 and 28 days, was situated between 2.01 and 4.40 MPa. In order to determine the super plasticizer saturation assay in of cement pasts used in self-compacting concrete, the study was completed by a rheological study with a variable velocity gradient, so as to estimate the quantity of saturation assay of superplasticizer and the formulation, also the flow models of cement pastE.

Rafat Siddique (2014) conducted the experiment and studied the effect of replacement of cement (by mass) with three percentage of fly ash and the effect of slump, vee bee consistometer, compressive strength, splitting tensile strength, flexural strength and impact strength of fly ash concrete. The cement was replaced with three percentage (35%, 45% and 55%) of fly ash. The test results indicated that the replacement of cement with fly ash increased the workability (slump and vee bee time) and compressive strength, splitting tensile strength, flexural strength and had no significant effect on the impact strength of plain (control) concrete.

Dilip Kumar Roy & Amitava Sil (2012) studied the Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete. 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) whereas 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.

Debabrata Pradhan et.al, 2013 stated that the mix proportioning is intricate and the design parameters are increased due to the incorporation of silica fume in conventional concrete. The aim of this paper is to look into the different mechanical properties like compressive strength, compacting factor, slump of concrete incorporating silica fume. In this present paper concrete incorporating silica fume are cast for 5 (five) mixes to perform experiments. Different percentages of silica fume are used for cement replacement in order to carry out these experiments at a single fixed water-cementitious materials ratio keeping other mix design parameters constant. The cement replacement level by silica fume was 0%, 5%, 10%, 15% and 20% for a constant water-cementitious materials (w/cm) ratio for 0.50. 100 and 150 mm cubes are used to determine the compressive strengths for all mixes at the age levels of 24 hours, 7 and 28 days. Besides the compressive strengths other properties like compacting factor, slump of concrete are also determined for five mixes of concrete.

Jun & Gengying (2016) studied the influence of fly ash in SCC. The filling and passing ability on fresh SCC containing fly ash were determined, with increase in the percentage of fly ash increased the slump flow and decreased the time taken for the concrete to flow through the V-funnel. The hardened concrete strength at 28 days diminished for an increase of fly ash in concrete, due to the slow pozzolanic reactivity of FA

Dinakar et al. (2008) investigated the durability characteristics of SCC with a high volume of fly ash as partial cement replacement material. The SCC mixes containing high volume fly ash qualified the standards of fresh concrete properties. It was highly workable with better flowability and good resistance to segregation. The mechanical properties enhanced at later ages containing fly ash in SCC.

Sukumar et al. (2008) developed a rational mix design method for SCC using fly ash as a mineral admixture at a high volume. The usage of a high amount of fly ash initiated the study on early age reactivity and strength gain. The compressive strength and splitting tensile strength for various grades of SCC were related and formulated.

Jeevetha et al.(2014) researched the effect of strength properties of SCC with microsilica, which flows under its own weight and does not require any external vibration for compaction. It was found that the compressive strength of cubes at 5% replacement was 28% higher than that of 10% replacement.

Alok (2016) studied the Partial Replacement of Cement in M-30 Concrete from Silica Fume and Fly Ash. Replacement levels of OPC by Silica Fume were 0%, 2.5%, 5%and 7.5% where replacement levels of Ordinary Portland cement by Fly Ash were 0%, 5%, 10% and 15% by weight. 1% super-plasticizer was used in all the test specimens for better workability at lower water cement ratio and to identify the sharp effects of Silica Fume and Fly Ash on the properties of concrete. Water-cement ratio was kept 0.43 in all cases. Author concluded 43.1 N/mm^2 was the maximum compressive strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.6.47 N/mm^2 was the maximum flexural strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.2.573 N/mm^2 was the maximum split tensile strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.

Iyappan & Jagannathan (2014) examined and found that 4%nanosilica in SCC showed an increase in compressive strength of 18.8%, flexure strength of 16.01% and splitting tensile strength of 23%. The increase in strength is due to a high surface area of Nano silica leading to improvement in the cement hydration process.

Summary of Literature

- SCC mixes show higher compressive and flexural strength and lower modulus of elasticity rather than the normal concrete.
- The compressive strength of the binary and ternary blends of SCC is performed with the split tensile strength of the controlled concrete with all binary and ternary concrete for all curing ages.
- By addition of some pozzolanic materials, the various properties of concrerte viz, workability, durability, strength, resistance to cracks and permeability can be improved.
- Fly ash and Silica fume is known to improve both the mechanical characteristics and durability of concrete.

PROPERTIES OF MATERIALS

General

For making SCC, it is essential to select proper ingredients, evalution of their properties and know how about the interaction of different materials for optimum usage. The performance requirements of concrete may involve enhancements of

- Ease of placement without segregation
- Long term mechanical properties.
- Early strength.
- Toughness.
- Volume stability.
- Longer service life.

Effective production of SCC is achieved by carefully selecting, controlling and proportioning of all ingredients. In order to achieve Self Compacting Concrete, optimum proportion must be selected considering the characteristics of cementitious materials, aggregate quality, paste proportions, aggregate paste interaction, admixture type, and dosage and mixing.

Cement

Lot of factors impact on the strength of concrete, but strength of cement is the most important and direct factor. Ordinary Portland Cement (OPC) 53 grade is used corresponding to IS-8112(1989). Throughout the investigation, a single batch of ultra-tech cement (OPC) is utilised. According to Indian standard code, various properties of cement are evaluated. The physical properties of cement is tabulated in Table 3.1

Table 3.1 Properties of Cement

S.No	Physical Properties	Results
1	Fineness	8%
2	Normal Consistency	28%
3	Initial setting time	75 minutes
4	Final setting time	215 minutes
5	Specific gravity	3.15
6	Compressive strength at 7-days	20.6 MPa
7	Compressive strength at 28-days	51.2 MPa

Fine Aggregate

Among various Characteristics, the most important factor for SCC is its grading. Fine Aggregate used for SCC should be properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contamination.

River sand is normally preferred over crushed sand since in the former; particle size is fully water worm by attrition which helps in reduction of water content of mix and also lesser resistance to pumping. SCC contains high quality of cement and fine particles in the form of micro silica and hence use of coarser sand is preferable. Properties such as voids ratio, gradation, specific surface and bulk density have to be assessed to design a dense SCC mix with optimum cement content and reduced mixing water. Locally available river sand is used in this investigation. Properties of fine aggregate and sieve analysis are presented in Table 3.2 and 3.3 respectively.

Table 3.2 Properties of fine aggregate

S.No	Name of the test	Value
1	Specific Gravity	2.62
2	Water absorption	0.65%
3	Bulk density	1750 kg/m^3
4	Fineness modulus	2.70
5	Moisture Content (%)	0.50

Table 3.3 Sieve analysis test of fine aggregate

I.S. Sieve Size	Weight retained (gm)	Cumulative weight retained (gm)	Cumulative percentage weight retained	Cumulative percentage weight passing
10 mm	3	3	0.6	99.4
4.75 mm	8	11	2.2	97.8
2.36 mm	17	28	5.6	94.4
1.18 mm	75	103	20.6	79.4
600 microns	232	335	67.0	33.0
300 microns	120	455	91.0	9.0
150 microns	42	497	99.4	0.6
< 150 microns	3	500	100.0	0.0

Coarse Aggregate

The coarse aggregate is the strongest and least porous component of concrete. Some important properties of coarse aggregate like crushing strength, durability modulus of elasticity, gradation, shape and surface texture characteristic, percentage of deleterious materials and flakiness and elongation indices need special consideration while selecting the aggregate for SCC. The coarse aggregate occupies more than 85% of the volume of concrete. The maximum size of the coarse aggregate was limited to 20 mm for control concrete and 12.5 mm for SCC. The properties and sieve analysis of coarse aggregates are listed in Tables 3.4 and 3.5.

Table 3.4 Properties of coarse aggregate

S.No	Name of the test	Value
1	Specific Gravity	2.67
2	Water absorption	0.5%
3	Bulk density	1600kg/ m^3
4	Aggregate Impact value	11.2
5	Aggregate Crushing value	24.95
6	Fineness modulus	7.03
7	Free Moisture Content (%)	0.2
8	Flakiness Index (%)	21.12

Silica Fume

Silica fume also referred as micro silica or condensed silica fume is another material that is used as an artificial pozzolanic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. When quartz are subjected to 20000°C reduction takes place and SiO vapours get into fuels. In the course of exit, oxidation takes place and the product is condensed in low temperature zones. In the course of exit, Silica fume rises as an oxidized vapour, oxidation takes place and the product is condensed in low temperature zones. When the silica is condensed, it attains non-crystalline state with ultra-fine particle size. The superfine particles are collected through the filters. It cools, condenses and is collected in bags.

It is further processed to remove impurities and to control particle size. Condensed silica fume is essential silicon dioxide (SiO_2) more than 90 percent in non crystalline form. Since it is an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000m^2/kg, as against 230 to 300 m^2/kg. The use of silica fume in conjunction with super plasticizer has been back bone of modern high performance concrete. High fineness, uniformity, high pozzolanic activity and compatibility with other ingredients are of primary importance in selection of mineral admixture. Physical properties of Silica fume and Chemical composition of silica fume are depicted in Tables 3.6 and 3.7.

Table 3.6 Physical properties of silica fume

Specification	Range obtained
Form/color	Powder/white/grey
Bulk density	600kg/m^3
Specific gravity	2.13

Table 3.7 Chemical composition of silica fume in %

Compound	Percentage by weight
SiO_2	**88.46**
Al_2o_3	**1.13**
Fe_2O_3	**0.86**

Advantages of Silica fume

High strength concrete made with silica fume provides high abrasion/corrosion resistance. Silica fume influences the rheological properties of fresh concrete, the strength, porosity and durability of hardened mass. Silica fume concrete with low water content is highly resistant to penetration of chloride ions. The extreme fineness of silica fume allows it to fill or pack the microscopic voids between cement particle and especially in the voids at the surface of the aggregate particles where the cement particles cannot fully cover the surface of the aggregate and fill the available space.

- Silica fume can also be proportioned as a water reducer with the reduction in water
- Cementitious material ratio, so it is hydrophilic in nature, thus super plasticizer
- Demand for additional water can be minimized.
- Silica fume reduces bleeding segregation of fresh concrete significantly.
- This effect is caused due to high surface area.
- Highly durable concrete can be obtained by improving the electrical resistivity of Concrete by the addition of silica fume.

Achieving adequate levels of durability in order to improve the performance and reduce the life cycle costs of concrete structures continues to be a serious problem for engineers. Benefits, in terms of high-strength concrete durability, of using additional binder materials. Some attempts were made to increase the early-age properties of the high-volume fly ash concrete by incorporating some activators and early-strength agents or small percentage (3%and 8.5%) of silica fume in the system. However, activators and early strength agents are generally alkaline substances, which may lead to alkali-silica reaction. At the same time, studies have shown that the use of silica fume did not significantly affect the early-age properties of the high-volume fly ash high-strength concrete (HFAC).

The results of a study by researchers suggest that certain natural pozzolana-silica fume combinations can improve the compressive and splitting tensile strengths, workability, and elastic modulus of concretes, more than natural pozzolana or silica fume alone. Jianyong and Pei concluded that blending and SF synergizes the advantages of these two admixtures so that the compressive strength, split tensile strength and rupture strength are improved while the fresh concrete mixture keeps a good workability.

Pozzolanic action of silica fume

Silica fume is much more reactive than any other natural pozzolana. The reactivity of apozzolana can be quantified by measuring the amount of Ca(OH)2 in the cement paste.15percentage of silica fume reduces the Ca(OH)2 of cement sample from 24% to 90% at 90days and from 25% to 11% in 180 days. The effect of silica fume can be explained by two mechanism i.e pozzolanic reaction and micro filler effect. The first product is calcium silicate-hydrate (C-S-H) gel, that is cementitious and binds the aggregate together in concrete and Ca(OH)2 The C-S-H formed by the reaction between micro silica and the product Ca(OH)2 which comprises 25% of volume of hydration product. Silica fume reacts with calcium hydroxide to produce more aggregate binding C-S-H gel. Simultaneously reducing Ca(OH)2. The net result is increase in strength and durability. the second mechanism is through the micro filler effect. The extreme fineness of silica fume allows it to fill or pack the microscopic voids. Sample of silica fume is depicted in Figure 3.1

Figure 3.1 Silica fume

Fly Ash

Fly ash is the most widely used supplementary cementitious material in concrete. It is a byproduct of the combustion of pulverized coal in electric power generating plants. Upon ignition in the furnace, most of the volatile matter and carbon in the coal are burned off. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called fly ash. The fly ash is then collected from the exhaust gases by electrostatic precipitators or bag filters. Fly ash is a finely divided powder resembling Portland cement. Class F fly ash is obtained from Mettur thermal power plant, Mettur, Tamilnadu, India. A Sample of fly ash is depicted in Figure 3.2. The physical and chemical properties of class F fly ash is listed in Table 3.8.

The benefits for using fly ash in concrete include the following:

- Improved workability,
- Lower heat of hydration,
- Lower cost concrete,
- Improved resistance to sulfate attack,
- Improved resistance to alkali-silica reaction,
- Higher long-term strength,
- Opportunity for higher strength concrete,
- Equal or increased freeze thaw durability,
- Lower shrinkage characteristics, and
- Lower porosity and improved impermeability.

Figure 3.2 Sample of fly ash

Table 3.8 Physical and chemical properties of fly ash

Specification	Limits
Silica (SiO_2)	52.36
Aluminium (Al_2O_3)	21.28
Iron (Fe_2O_3)	12.56
Calcium (CaO)	7.92
Magnesium (MgO)	2.07
Loss On Ignition (LOI)	0.86
Specific Surface Area(m^2/Kg)	856
Specific gravity	1.95
Colour	Light grey
Fineness (m^2/Kg)	287

Chemical Admixtures

Super plasticizer has strong dispersion effect, it can greatly increase the flow of mixed cement and concrete slump and also water consumption, improving the concrete and increasing its durability of strength. Super plasticisers (SP) or high range water reducing admixtures are an essential component of SCC.

Conplast SP430 is used as super plasticiser (conforming to IS: 9103:1999). The properties of the chemical admixtures as obtained from the manufacturer are presented. Properties of Chemical Admixtures Confirming to EN 934-2 and SIA162 (1989). Table 3.9 shows the properties of chemical admixture.

Table 3.9 Properties of chemical admixtures

Properties	Value
Color	Brown
Specific gravity	1.19
Chloride Content	Nil
Air entrainment	<1%

Water

Mixing water quality is required in accordance with the quality standards of drinking water, the use for PH> 4 clean water. Potable water is used for mixing and curing of the SCC mixes.

EXPERIMENTAL PROGRAMME

Object of testing

The Experimental programme consists of arrival of Mix proportion of SCC for the selected grade of concrete, specimens casting and testing.

SCC Mixing Procedure

The mixing procedure involves the following steps:

1. After starting mixer, coarse and fine aggregate were added into drum and homogenized for 30 seconds.
2. Cement and SCM (FA or SF) were then added within 10 seconds of stopping Period and then mixing continued for 30 seconds.
3. 60% of water mixed with super plasticizer was then distributed all over the mix and mixing continued for 30 seconds.
4. Remaining 40% of water mixed with super plasticizer was added and mixed for 60 seconds.
5. Stop and rest for 30 seconds.
6. Starting again the mixer and dispersion by hand gradually over concrete mix within 60 seconds.
7. Mixing continued for additional 120 seconds and then stopped.

Table 4.1 Mix proportions for M25 grade of concrete

Cement kg/m^3	**Fine aggregate** kg/m^3	**Coarse aggregate** kg/ m^3	**Water lit/m^3**
524.31	788.77	773.06	199.24
1	1.5	1.47	0.38

Converting to SCC proportions

The normal design mix is converted to SCC proportions and then the fresh properties of concrete are considered and we arrive at a final mix design. The mix proportion for self-compacting concrete is obtained by trial and error method. Using EFNARC regulations. The mix proportion for 1 m^3 of SCC is presented in Table 4.2

Cement = 524.31 kg/ m^3
Fine aggregate (F.A.) = 788.77 kg/ m^3
Coarse aggregate (C.A.) = 773.06 kg/ m^3
Total aggregate (T.A) = 788.77+773.06 = 1561.83 kg/ m^3
Taking F.A : C.A. as 60%:40%
Fine aggregate =937.08kg/ m^3
Coarse aggregate =624.73kg/ m^3

Table 4.2 SCC Mix proportions

Cement kg/m^3	**Fine aggregate kg/m^3**	**Coarse aggregate kg/m^3**	**Water lit/m^3**	**Super plasticizer**

524.31	788.77	773.06	199.24	1.2%
1	1.5	1.47	0.38	

Table 4.3 Mix Identification

Designation	Mix combination
CM	CONVENTIONAL MIX
SSC1	SF 0%+FA25%
SSC2	SF5%FA20%
SSC3	SF10%+FA15%
SSC4	SF15%+FA10%
SSC5	SF20%+FA5%
SSC6	SF25%+FA0%

CONCLUSIONS AND WORK SCHEDULE FOR PHASE II

The following conclusions have been made based on the Phase I studies

- ✓ The research objective, need for study and advantages of SCC are discussed.
- ✓ Literatures have been reviewed as per the proposed title and summary of conclusions have been included
- ✓ Various materials have been tested for their physical and chemical properties.
- ✓ Mix design and their corresponding SCC mix design are summarized
- ✓ Mix identification and mix combination of FA and SF replaced concrete are included at the end of chapter 3

WORK SCHEDULE FOR PHASE II

- Fly ash and Silica fume will be replacing by various proportions by the weight of cement in SCC
- The influence of pozzolanic materials in self-compacting concrete will be evaluated.
- Fresh characteristics concrete test on SCC such as slump flow, V-funnel flow time and L-Box ratio will be determined.
- The various mechanical and durabilty strength properties will be studied and those test results will be compared with conventional concrete mix.

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