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"EXPERIMENTAL STUDY OF SELF COMPACTING CONCRETE FOR PARTIAL REPLACEMENT OF CEMENT BY FLY ASH AND SILICA FUME"

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ABSTRACT

The Self-Compacting Concrete (SCC) is that which gets compacted due to its self-weight and is deaerated (no entrapped air) almost completely while flowing in the form work. In recent times self-compacting concrete has been accepted as a quality product and are widely used. The addition of fly ash and silica fumes to concrete imparts superior mechanical properties to Self Compacting Concrete. The aim of this project work is to study the strength behavior of SCC partial replacement of cement with fly ash and silica fumes. Fly ash silica fume Self Compacting Concrete (FASF SCC) has been cast with volume fractions of 00%, 05%, 10% and 15% of silica fumes based on “Nan Su et.al” method and tested after 28 days of normal curing. This work also comprises the study of the effect of steel fibers on workability in fresh state and the compressive strength of cubes (150mmx150mmx150mm), split tensile strength of cylinders (diameter 150 mm and height 300mm), modulus of rupture of beams (100mmx100mmx500mm) in hardened state after 7,14, and 28 days of normal water curing. The results showed that the ultimate strength has increased marginally. The optimum volume fraction of silica fumes for better performance in terms of strength and ductility has been found to be 10%. Based on the results obtained from the investigations and after rational discussion, the conclusions have been developed on the fresh state properties of FASF SCC, hardened properties of FASF SCC, and the optimum dosage of silica fume.

CHAPTER I INTRODUCTION

1.1 GENERAL

Self-compacting concrete (SCC) is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. Self Compacting Concrete was developed in Japan in the late 1980s as a solution to achieve durable concrete structures independent of the quality of the construction work. Self-consolidating concrete or self-compacting concrete (SCC) is characterized by a low yield stress, high deformability, and moderate viscosity necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets. SCC ensures a good balance between deformability and stability. Moreover, the high workability of SCC results in a well compacted microstructure with reduced porosity in mortar matrix and interfacial transition zone. figure 1.1 shows the basic principles for the production of SCC.

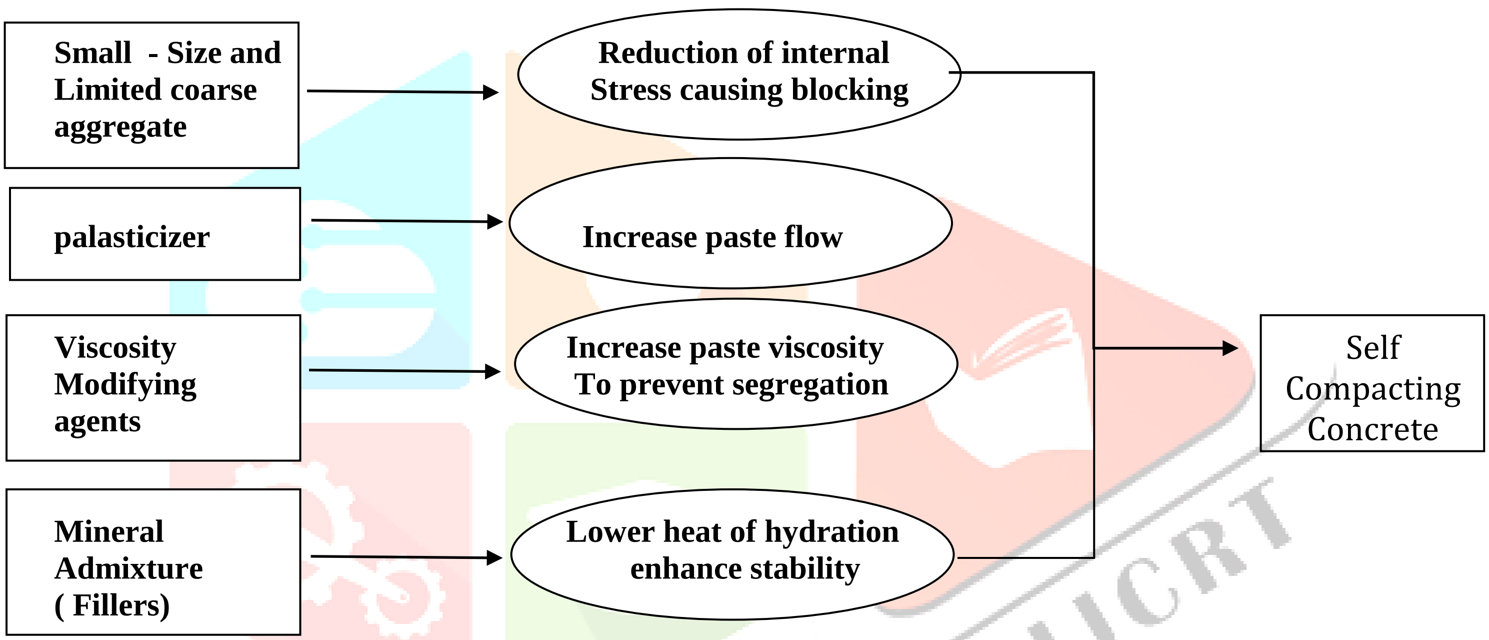

Fig. 1.1: Basic Principles For Production of Self-Compacting Concrete

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete.

admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Silicon metal and alloys are produced in electric furnaces as shown in this photo. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being land filled. Perhaps the most important use of this material is as a mineral admixture in concrete.

Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high content, silica fume is a very reactive pozzolan when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

According to EFNARC, the benefits of SCC over conventional concrete:

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of Vibrators.
- Substantial reduction of environmental noise loading on and around a site.
- Better surface finishes.
- Easier placing.
- Thinner concrete sections.
- Greater Freedom in Design.
- Improved durability, and reliability of concrete structures.
- Ease of placement results in cost savings through reduced equipment and labor requirement.

1.2 OBJECTIVE OF PROJECT WORK

Self-compacting concrete is required to have three qualities: high-flowability, resistance to segregation and passing ability. Objective of this work is to judge the workability of the self-compacting concrete in its fresh state by following methods:

- Slump Flow Test for Measuring Flow ability of concrete mix.
- J-Ring Test to determine the passing ability of concrete mixtures.
- The V-funnel test to measure the filling ability of self-compacting concrete and can also be used to judge segregation resistance.
- The L-box test to examine the filling and passing ability of self-compacting concrete. The test is also applicable for highly flowable concrete.

Hence this work is to study of the effect of steel fibres reinforced self compacting concrete on workability in fresh state and the compressive strength of cubes (150mmx150mmx150mm) in hardened state after 7, 14, and 28 days of normal water curing. The fly ash and silica fume self compacting concrete of M30 grade of (FASFSCC) has been cast with volume fractions of fly ash fix at 20% and silica fume is ,0%, 5%, 10% and 15 % tested after 28 days of normal curing and investigated to evaluate the effect of the different parameters on the performance of FASFSCC.

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- The L-box test to examine the filling and passing ability of self-compacting concrete. The test is also applicable for highly flowable concrete.

The objective of this experimental work is to study the flow characteristics of FASFSCC and the influence of fibres on its mechanical properties. The scope of this work includes:

- To design is mix by Nan-Su method in order to produce M30 grade of self-compacting concrete.

- To determine the optimum silica fume content to be added without hindering the flow characteristics of SCC.
- Workability of FASFSCC according to EFNARC guidelines for Slump- test, V- Funnel-test, L-Box test and J-Ring test.
- To determine the effects of fibres on the hardened properties of SCC through measurements.
- To determine the effects of mineral admixture on the hardened properties of concrete.

1.3 RESEARCH METHODOLOGY

- Literature study on the workability parameters, test methods for workability of SCC, performance of SCC in hardened state and its compression behaviour.
- Mix Design of M30 grade SCC by Nan-Su Method.
- Effect on properties of SCC by adding Steel fibres.
- Workability study of FASFSCC mix according to EFNARC guidelines for Slump test, V-Funnel test, L-Box test and J-Ring test.
- Hardened properties of SFRSCC have been tested by Compressive Strength of cube specimens (150mm x 150mm x 150mm) at 7, 14, 28 days of maturity in normal water curing.
- Finally discussion of all test results along with their theoretical expressions has drawn and all results have compared and justified.

1.4 ORGANISATION OF RESEARCH WORK

This thesis work has been divided into various chapters in order of the execution of the experimental work as described below.

Chapter 1-Introduction

This chapter deals with the Introduction to the topic (FASFSCC), influence of mineral admixture on properties of SCC, the objectives and scope of the project work and the research methodology.

Chapter II- Review of Literatures

This chapter deals with the Review of Literatures used in the project work. Various studies related to the performance of FASFSCC, its axial loading behaviour and the theoretical expression for the moment carrying capacity of FASFSCC is mentioned in this chapter.

Chapter III-Experimental Programme

This chapter deals with the methodology part of this experimental work. It contains the experimental work plan of the project work which specifies the materials used in the project work along with their quantities required for experimentation based on the mix design. Also the type of mix design to be used in this project has been noted based on the guidelines specified by EFNARC. It contains specimen detailing used in this work along with their casting and testing methods. It comprises the test procedures used to determine the different fresh and hardened properties of SCC and its behaviour.

Chapter IV- Experimental Results

This chapter deals with the experimental results of FASFSCC which include the results of FASFSCC in fresh as well as hardened state. All the tests have been performed as per Indian standard code specifications and results have been compared and justified.

Chapter V- Discussion of the Test Results

This chapter of the thesis deals with the results obtained from experimental work and its rational discussion of FASFSCC.

Chapter VI- Conclusions and Future Scope of the work

This part of thesis deals with the conclusions and the future scope of this work. Based on the experimental results obtained and its rational discussion, conclusions were made which will specify the future perspective and recommendations of the project work done.

CHAPTER II LITERATURE REVIEW

2.1 GENERAL

The concept of Self-Compacting Concrete (SCC) was proposed by Prof Okamura (1999) at Tokyo University, Japan in 1988. The studies on the workability of concrete were carried out by Ozawa and Maekawa (1989). The developments in the technology of Self-Compacting Concrete (SCC), in the last era, have led to the development of admixtures and innovative concept about granular packing and mix design criteria for workability and fresh state performance of FASFSCC and have thus made possible the successful design and casting of fly ash silica fume Self-Compacting Concretes.

2.2 DEVELOPMENT OF SELF COMPACTING CONCRETE

Self-compacting concrete has high flow ability and a moderate viscosity, and no blocking may occur during flow. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo (1989). SCC was designed to achieve high flow rate and also to avoid obstruction by closely spaced reinforcements by making use of low size aggregates and their grading. This type of concrete was designed by using high fine to coarse aggregate ratio, low water cementitous material, good aggregate grading and high range water reducing admixture and Viscosity modifying admixture. The transition zone in this type of concrete is free from micro cracks. Several mix design methods for SCC were proposed by Okamura and Ouchi (1999), Petersson and Billber (1999) and Sedran and De Larrard (1999). European Federation of natural Trade associations representing producers and applicators of Specialist building products (EFNARC) has drawn up specifications and guidelines for Self-Compacting Concrete to provide a framework for design and use of high quality SCC, during 2002.

Nan Su et al (2001) passed out an investigation on a simple mix design for Self-Compacting Concrete and is much simpler when compared to Japanese Ready-Mixed Concrete Association (JRMCA) as it is easier for implementation and also consumes less time, also it requires a smaller amount of ring binder thus saves cost effectively. According to different investigators [9-11] the high workability of SCC results in a well compacted microstructure with reduced porosity in mortar matrix and the interfacial transition zone, and thus improves the electrical resistivity and transport properties of concrete.

A compressive review of literature related to the properties of Self-Compacting Concrete when mixed with different types of additives like Silica fume, fly ash, hydraulic lime and a mixture of fly ash and hydraulic lime was studied by Zoran Grdic et al (2008). Research scholars all over the globe have reported the need of admixtures in SCC. H. Okamura & M. Ouchi (1997) have investigated the effect of superplasticizer on the balance between flowability and viscosity of mortar in SCC.

Nan Su et al (2001), Okamura H (2003) and EFNARC guidelines (2002 & 2005) have proposed the mix design methods for SCC using different mineral admixtures. Suresh Babu. T (2009) has studied elaborately about stress-strain behaviour of SCC and GFRCC with different admixtures.

As per experimental report of Papworth (1994), various models for the stress-strain behaviour of conventional, fibre reinforced and steel fibre reinforced self-compacting concrete mixes were presented. Annie Peter (2007) have reported the flexural behaviour of steel fibre reinforced SCC.

2.3 EFFECT OF MINERAL ADMIXTURE ON THE BEHAVIOUR OF CONCRETE

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 is subjected to 2000°C reduction takes place and 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 super fine 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) 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 as against 230 to . 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. As Silica fume has the minimum fineness of , whereas the fumed Silica has the fineness of , which is 6 to 7 times finer than Silica fume. Finer the particle of pozzolano, higher will be the modulus of elasticity, which enhances the durability characteristics of the High-performance concrete.

Silica fume, also known as microsilica, is a by-product of the silicon and ferrosilicon alloy production process. It is a highly reactive and fine-grained material, consisting of amorphous silica particles. Silica fume is typically collected from the exhaust gases of electric arc furnaces during the production of silicon and alloys. Silica fume is widely used as a supplementary cementitious material (SCM) in the production of concrete due to its unique properties. Here is an introduction to silica fume and its uses in the concrete-making process. Pozzolanic Reactivity: Silica fume is highly pozzolanic, meaning it reacts chemically with calcium hydroxide (lime) in the presence of water to form additional hydration products. This reaction produces a denser and more refined microstructure in concrete, resulting in improved strength, durability, and reduced permeability. High Strength and Durability: The addition of silica fume to concrete mixtures leads to significantly increased compressive strength, flexural strength, and abrasion resistance. It also improves the resistance of concrete to chemical attack, chloride penetration, and sulfate attack, making it highly durable in aggressive environments.

Both fly ash and silica fume as filler materials offer several advantages in SCC, such as improved strength, reduced permeability, enhanced workability, and increased durability. The specific dosage and combination of fly ash and silica fume may vary depending on the desired properties, local material availability, and mix design requirements. Extensive testing and optimization are necessary to determine the most effective combination and proportion of fillers in SCC. In SCC, both fly ash and silica fume can be used individually or in combination, depending on the desired properties and project requirements. The optimal dosage of fly ash and silica fume should be determined through mix design considerations and testing to achieve the desired fresh and hardened properties of SCC.

2.4 ADVANTAGES AND USES OF FLY ASH AND SILICA FUME

This literature review provides a comprehensive analysis of the effect of incorporating fly ash and silica fumes in self-compacting concrete. It highlights the significant improvements in workability, strength, durability, and sustainability that can be achieved through the addition of these supplementary cementitious materials. The review also addresses the challenges and limitations associated with their use in SCC and suggests potential areas for future research. Overall, this study contributes to the existing knowledge on optimizing the properties of self-compacting concrete by utilizing fly ash and silica fumes as sustainable alternatives. By reviewing and synthesizing previous literature reviews on the effect of fly ash and silica fumes in self-compacting concrete, this article provides an overview of the cumulative knowledge in this field. It highlights the common findings, research gaps, and future directions, offering valuable insights for researchers, engineers, and practitioners interested in utilizing supplementary cementitious materials in SCC. By examining the existing literature on the topic, this review provides a comprehensive understanding of the effect of incorporating fly ash and silica fumes in self-compacting concrete. The findings highlight the potential benefits of these supplementary cementitious materials in improving both the fresh and hardened properties of SCC, while also considering mix design considerations, curing regimes, rheological behavior, environmental aspects, and challenges associated with their use. The review concludes by suggesting areas for future research to further enhance the understanding and application of fly ash and silica fumes in self-compacting concrete.

Bouzoubaa and Lachemi (2001) carried out an experimental investigation to evaluate the performance of SCC made with high volumes of fly ash. Nine SCC mixtures and one control concrete were made during the study. The content of the cementations materials was maintained constant (400 kg/m^3), while the water/cementations material ratios ranged from 0.35 to 0.45. The self-compacting mixtures had a cement replacement of 40%, 50%, and 60% by Class F fly ash. Tests were carried out on all mixtures to obtain the properties of fresh concrete in terms of viscosity and stability. The mechanical properties of hardened concrete such as compressive strength and drying shrinkage were also determined. The SCC mixes developed 28-day compressive strength ranging from 26 to 48 MPa. They reported that economical SCC mixes could be successfully developed by incorporating high volumes of class F fly ash.

Sri Ravindra rajah (2003) et al made an attempt to increase the stability of fresh concrete (cohesiveness) using increased amount of fine materials in the mixes. They reported about the development of self-compacting concrete with reduced segregation potential. The systematic experimental approach showed that partial replacement of coarse and fine aggregate with finer materials could produce self-compacting concrete with low segregation potential as assessed by the V-Funnel test. The results of bleeding test and strength development with age were highlighted by them. The results showed that fly ash could be used successfully in producing self compacting high-strength concrete with reduced segregation potential. It was also reported that fly ash in self-compacting concrete helps in improving the strength beyond 28 days. Self-Compacting Concrete.

Bhanja And Sengupta et.al(2005) Obtained in the range of 15% to 25% silica fume replacement Silica fume incorporation in concrete results in significant improvements in the flexural strength of concrete, along with the compressive strength. Duval and Kadri et al (1998) Silica fume content up to 20% and reaches a maximum for a 10 to 15% silica fume level. Found that the compressive strength of concrete increases.

Mazloom, et al (2004) found that the compressive strength development of concrete mixtures containing silica fume was negligible after the age of 90 days; There were strength increases in the control concrete even after one year and the reason behind this can be attributed to the rapid formation of a layer which prevents reaction of silica fume with calcium hydroxide beyond 90 days.

Perumal & Sundararajan et.al (2004) observe the Effect of partial replacement of cement with silica fume The results also show that the SF concretes possess superior durability properties. Chatterjee, et al (2011) One may achieve up to 70% replacement of cement with fly ash when high strength cement and very high reactive fly ash is used along with the sulphonated naphthalene formaldehyde superplasticizer. He reported improvement in fly ash property could be achieved by grinding and getting particles in sub microcrystalline range. Poon, Lam &

Wong.et.al (1999) Concluded that replacement of cement by 15% to 25% by fly ash results in lower porosity of concrete and plain cement mortars.

J. M. Srishaila et al studied the Influence of Fly Ash and Silica Fumes on the Behavior of Self Compacting Concrete. In this study, A test examination is done to consider the properties of SCC, by somewhat supplanting concrete with certain level of Fly fiery debris and Silica smolder. Further, Workability, Mechanical and Durability properties are considered on these SCC blend extents.

Victor Ajileye Faseyemi investigated the use of micro silica and fly ash in self compacting concrete. In this study, the exploratory program was intended to research into the utilization of fly ash remains, micro silica in self compacting concrete. The substitution levels of bond by fly fiery remains, micro silica are chosen as 35%, 30%, 25%, 15% and 10% for fly cinder while micro silica are 10%, 8%, 6%, 4% and 2% for standard size of cubes for C 50 review of self compacting concrete. The examples of standard solid shapes (150 X 150 X 150 mm) were thrown with fly fiery debris, micro silica. Compressive machine was utilized to test every one of the examples. The examples were thrown with C 50 review concrete with various substitution levels of bond from 0-35% with fly fiery remains, superplasticizer and gooey modifier while substitution levels of bond from 0 to 10% with micro silica. Hundred examples were thrown and the cubes shapes were placed in curing tank for 3, 7, 28 and 56 days and thickness of the blocks and compressive quality were resolved and recorded appropriately. Usefulness was resolved utilizing droop stream, V-channel, L-Box as per the standard utilized. This study shows that micro silica and fly ash at 2% and 10% replacement in self compacting concrete was the best design and it developed strength sufficient for construction purposes. These replacements led to a reduction in cement quantity required for construction purposes and hence enhance sustainability in the construction as well as aid economic construction.

The present work deals with a mix of fly ash and silica fume with constant and varying volume fraction of silica fume 0%, 5%, 10% and 15%. The goal of this study is to determine the effect of introduction of fly ash and silica fume on SCC in terms of the following.

- Workability of FASFSCC.
- Compressive strength.
- behaviour at different volume fraction of steel fibres of FASFSCC.

2.5 CONCLUDING REMARKS

Extensive research on FASFSCC in recent years and its various advantages in various civil engineering application have been discussed in this chapter. The effect of addition of fly ash and silica fume in SCC in compression members is to be investigated. Accordingly, the experimental program has will be discussed in next chapter.

CHAPTER III EXPERIMENTAL PROGRAM

3.1 GENERAL

This part of the thesis includes the total methodology and the materials used including their properties, both physical and chemical. The first part comprises the physical and chemical properties of the materials used in the study. The second part describes the mix design adopted in the study and the third part includes the methods adopted to study the fresh properties and the hardened properties of FASFSCC. For the point of view of quality control, concrete of same strength is required to be used throughout the research work, it means that the physical and chemical properties of all the constituents remains same. The present chapter of the thesis includes the laboratory tests used to assess the characteristics of the different materials used in FASFSCC.

3.2 MATERIALS USED

- Cement.
- Aggregate.
- Fly Ash.
- Silica fume.
- Superplasticizer.
- Viscosity Modifying Agent etc.

3.2.1 Cement In this present investigation Ordinary Portland Cement (OPC) of 53-grade obtained from AMBUJA Cements Pvt. Ltd was used conforming to IS 12269-2004 was used. As per IS 4032 for the chemical composition of OPC53. Specific Gravity was found out 3.04 for OPC of 53-grade cement. figure 3.1 shows the cement used in the experimental work. Table 3.1 shows the physical properties of cement used.

Figure 3.1: OPC 53 Grade Cement

Table 3.1: Physical Properties of OPC 53 Grade Cement

S. No	Properties	Results obtained	IS:12269:2004 Specifications
1	Fineness retained on IS sieve 90μ	4%	<10 (max)
2	Soundness (mm)	3	<10 (max)
3	Normal Consistency	35%	—
4	Initial Setting Time	60	>30 (min)
5	Final Setting Time	344	<600 (max)
6	3 days compressive strength (MPa)	26.6	>27
7	7 days compressive strength (MPa)	36.2	>37
8	28 days compressive strength (MPa)	56	>53
9	Specific Gravity	3.04	3.15

3.2.2 Fine Aggregates.

Locally available sand from river with 4.75 mm maximum size was used as fine aggregate. The corresponding specific gravity and bulk density of fine aggregate used were 2.55 and 1600 kg/m³ respectively, both confirming to IS 383-1970. The fineness modulus of fine aggregate was found to be 2.65 of zone II.

3.2.3 Coarse Aggregate

Locally available crushed stone with maximum size 16mm was used as coarse aggregate. The corresponding specific gravity and bulk density of coarse aggregate used were 2.78 and 1560 kg/m³ respectively, both confirming to IS 383-1970. Coarse aggregates having a maximum size of 16mm were used in this project work where 40% of it was passing through 16mm IS sieve and retaining on 12.5mm IS sieve and 60% was passing on 12.5mm IS sieve and retained on 4.75mm sieve. The fineness modulus of coarse aggregate was found to be 6.78.

3.2.4 Fly Ash

Class F Fly ash of specific gravity 2.44 and conforming to IS 3812-2003 procured from "Usha Martin Plant" Ranchi has been used as a Mineral Admixture as additives in SCC concrete mixes. Chemical properties of fly ash are given in Table 3.2.

Table 3.2: Chemical Properties of Fly Ash

Chemical Composition	SiO_2	$AI2O_3$	$Fe2O_3$	CaO	MgO	TiO_2	SO_3	LOI
% by Mass	65.6	28.0	3.0	1.0	1.0	0.5	0.2	5.02

3.2.5 Super Plasticizer

Commercially available super plasticizer CHRYSOPLAST Delta-K710 obtained from Structural Waterproofing Company, Kolkata has been used as super plasticizer. Superplasticizer was mixed in the amount of 6.3 ml/kg of cement confirming to IS 9103-2004. The specific gravity and pH of super plasticizer used are 1.12 and 5.0 respectively. Super plasticizers are introduced in SCC to obtain the fluidity. Nevertheless, a high dosage near the saturation amount can increase the proneness of the concrete to segregate.

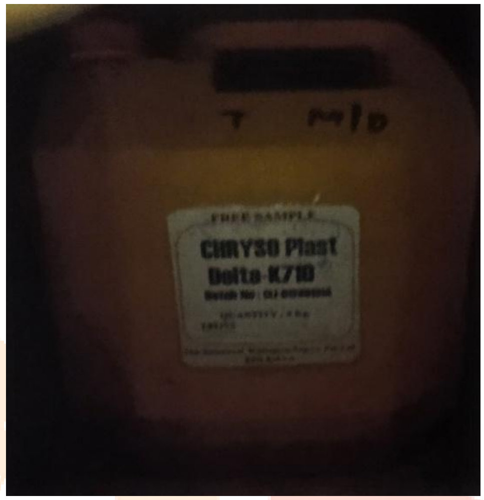

Figure 3.2: Superplasticizer

3.2.6 Viscosity Modifying Admixture (VMA)

Viscosity Modifying Admixture (VMA) obtained from Oswal Engg. And Chemical Company, Ranchi was used in the experimental programme having a pH of 7.0. These products are generally cellulose derivatives, polysaccharides or colloidal suspensions. These products have the same role as the fine particles, minimizing bleeding and coarse aggregate segregation by thickening the paste and retaining the water in the skeleton. The introduction of such products in SCC seems to be justified in the case of SCC with high water to binder ratio.

Figure 3.3: Viscosity Modifying Agent

3.2.7 Silica fumes

Silica fume, also known as micro silica, is a by-product of the production of silicon and ferrosilicon alloys in electric arc furnaces. Silica fume is produced as a by-product during the production of silicon metal and ferrosilicon alloys. These alloys are commonly used in the steel and aluminium industries. The process involves the reduction of high-purity quartz or silicon dioxide) with carbon in an electric arc furnace. In the electric arc furnace, the high temperatures (around 2,000 to 2,200 degrees Celsius) vaporize the silica content of the raw materials. The silica vapour reacts with oxygen in the furnace atmosphere, resulting in the oxidation of the silicon and the formation of ultrafine particles of amorphous silica. The silica fume particles, which are extremely fine and typically range in size from 0.1 to 0.3 micrometers, are carried along with the off-gas from the electric arc furnace. The off-gas containing the silica fume is directed to a collection system, typically consisting of filters or baghouses. The off-gas is passed through the collection system, which captures and separates the silica fume particles from the gas stream. The collection system usually employs high-efficiency filters or baghouses that can effectively capture the fine silica fume particles while allowing the clean gas to pass through. Once the silica fume has been collected and separated, it is typically transported to a processing facility where it undergoes additional treatment, such as drying and densification, to improve its handling and storage characteristics. After processing, the silica fume is packaged in bags, bulk bags, or silos for distribution to end-users, such as concrete producers, to be used as a supplementary cementitious material in various construction applications.

Fig: Silica fume

3.2.8 Water

In this study, normal tap water available in the concrete laboratory was used. Water conforming to the requirements of water for concreting and curing as per IS: 456-2000.

3.3 MIX PROPORTION OF SCC

3.3.1 Method of Mix Design for SCC

The method of mix design used in this experimental study is Nan-Su method. Initial trail mixes are obtained from Nan Su mix design procedure and mixes are modified according to get fresh, hardened properties and hardened properties. Among them the bold ones satisfy the specifications and economical mixes. From the obtained mixes a simplified mix design was developed for SCC on the lines of Nan-su method using ordinary Portland cement and fly ash. Nan-Su method is the only method that specifies the grade of concrete in SCC. The procedure is described in the following steps. The method of mix design used in this experimental study is Nan-Su method. Nan-Su method is the only method that specifies the grade of concrete in SCC. The main limitation of this method is it gives required mix proportions for the grades which are more than M50. Hence certain modifications were made by Vilas V. Karjinni and Shrishail. B. Anadinni and this method was used for mix design of SCC for grades less than M50 by taking a correction factor. One of the significant limitations in the ready adoption of self-compacting concrete in India is the lack of availability of appropriate mixture proportioning methods. In the mixture proportioning of SCC the quantities to be determined are air, water, cement, filler, fine and coarse aggregate apart from the dosages of superplasticizer and viscosity modifying agent. All the methods developed are based on the guidelines given by the scholars in the field of SCC along with number of trials in the laboratory and in the field.

Nan-Su Method

1. **Calculation of Quantity of Fine and Course Aggregates.**

This can be determined by knowing the packing factor (PF).

W_{fs}=PF x W_{xs} x s/a

W_{ca}=PF x W_{cal} x (1- s/a)

Where,

Wfa-- Mass of FA per cum

Wca-- Mass of CA per cum

Wfal-- Unit volume mass of FA

Wcal-- Unit volume mass of CA

S/a-- Ratio of FA to the total mass of aggregate

2. Calculation of Cement Content

C= fc/0.14

Where,

fc-- designed strength of concrete

3. Calculation of Mixing Water Content

W_{wc}= W/C x C

Where,

C -- Compressive strength, of cement

W_{wc}-- Mixing water content required by cement

W/C-- The Water - Cement ratio by weight.

4. Calculation of filler

Vpf= 1-(Wca/1000 x Gca) -(Wfa/1000 x Gfa)-(C/1000 x Gw)- Va

Wf= [Vpf x 1000 x Gr]/[1+(W/P) x Gf]

Where,

- W_f - Mass of filler
- V_a - Air content in %
- G_r - Sp. Gravity of filler
- w/p - water powder ratio
- $W_{wf} = W / F \times W_f$

5. Calculation of Mixing Water Content Needed In SCC

$W_w = W_{wc} + W_{wf}$

6. Calculation of Super plasticizer and VMA dosage

The superplasticizer and VMA dosage can be determined from experience or from its saturation point.

The calculation made and the results obtained for M30 grade of SCC by this method are given below and the results are tabulated in Table 3.4.

1. Calculation of Quantity of Fine and Coarse Aggregates

$W_{fa} = PF \times W_{tal} \times s/a$

$W_{fa} = 0.95 \times 1600 \times 0.56$

$W_{fa} = 851.20$

$W_{ca} = PF \times W_{cal} \times (1 – s/a)$

$W_{ca} = 0.95 \times 1560 \times 0.44$

$W_{ca} = 652.08$

2. Calculation of Cement Content

C = CF × (fc / 0.14)

C = 1.75 (41.7 / 14)

C = 521.25

3. Calculation of Mixing Water Content

$W_{wc} = W / C \times C$

$W_{wc} = 0.44 \times 521.25$

$W_{wc} = 229.35$

4. Calculation of Filler

$W_{pf} = 1 - (W_a/1000 \times G_a) - (W_s/1000 \times G_n) - (C/1000 \times G_c) - (W_l/1000 \times G_l) - V_f$

$W_{pf} = 1 - (0.238 - 0.274 - 0.158) - (0.232) - 0.02$

$W_{pf} = 0.078$

$W_f = [W_{pf} \times 1000 \times G_d] / [1 + (W/p) \times G_r]$

$W_f = [206.71 / (2.65)]$

$W_f = 78.00$

5. Calculation of Mixing Water Content Needed In SCC

$W_w = W_{wc} + W_f$

$W_w = 229.35 + 41.7$

$W_w = 271.05$

Table 3.4: Mix Proportion of SCC

Mix proportion	Cement kg/m³	Fly ash and silica fume kg/m³	Fine Aggregate kg/m³	Coarse Aggregate kg/m³	Water kg/m³
	521.25	78	851.20	652.08	271.05
	1	0.14	1.63	1.25	0.52

Table 3.5 shows the calculation of Superplasticizer and VMA dosage to be added to the mix proportion. Here, the VMA and superplasticizer dosage are calculated by trial and error method by maintaining a constant VMA dosage and by varying the superplasticizer dosage as previous research.

Table 3.5: Superplasticizer and Viscosity Modifying Admixture (VMA) dosage

Trial No.	Superplasticizer	VMA	Slump test (mm)	T50 (sec)	V-Funnel test (sec)	L-Box test
1	0.7%	0.24	320	14	18	0.55
2	0.8%	0.24	390	11	16	0.65
3	0.9%	0.24	460	9	13	0.70
4	1.0%	0.24	570	7	11	0.80
5	1.1%	0.24	650	4	9	0.90

3.4 PREPARATION OF FASFSCC MIXES

The mixing is done manually as hand mixes. The coarse and Fine aggregates are dried for about 30s. This is then followed by the addition of Cement, Fly ash and silica fume and about 1/3 of the total mixing water. After mixing is done remaining water along with superplasticizer and VMA are added and mixed thoroughly. And then the mixes were checked for fresh properties and the casted in specimen moulds for checking the hardened mixes. This wet composition is allowed to mix for four minutes. During the process, fibre was sprinkled uniformly in the wet mixture. The moulds were filled with the mix prepared. After 24 hours the specimens are demoulded and are transferred to curing tank for normal water curing at 7, 14, and 28 days of maturity.

After 24 hours of casting, specimens are kept for 28 days normal water curing without disturbance until it attains a hardened state. Fly ash and silica fumes added in the proportions of 0.0% (reference mix), 5%, 10% and 15% for all mixes to cast various FASFSCC specimens. To facilitate the presentation of the experimental results, each concrete mix was identified by the letter SF followed by its mineral content in percentage, i.e. FASF-0.0, FASF-5, FASF-10 and FASF-15 as mentioned in Table 3.6.

Table 3.6: SFRSCC Mixes

MIX Designation	% SF
FA15SF-0	0%
FA15SF-05	5%
FA15SF-10	10%
FA15SF-15	15%

3.5 TESTS ON FRESH PROPERTIES OF FA/SPCC

The experimental investigations made on self compact ability of concrete can be characterized by the following properties.

- Filling ability.
- Passing ability.
- Segregation resistance.

A concrete mix can only be classified as self-compacting concrete if the requirements for all three characteristics are fulfilled.

Many different methods have been developed to characterize the properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects, and hence, each mix has been tested by more than one test method for the different workability parameters. The various tests done to check the workability are Slump test, V-Funnel test, L-Box test and J-Ring test. According to the experimental investigations to keep self-compacting effect of mixtures modified with mineral admixture, the volume fraction of maximum 20% seems to be recommended to ensure its maintenance. Hence volume fractions of up to 15% have been taken in this experimental work.

3.5.1 Slump Flow Test

The simplest and most widely used test method for Self Compacting Concrete is the slump flow test (EFNARC 2002). The test, which was developed in Japan, was originally used to measure underwater concrete and has also been used to measure highly flowable concrete. This test method evaluates the ability of the SCC to flow under its own weight in an unconfined condition. To perform the test, a conventional slump cone is placed on a flat surface.

rigid, non-absorbent plate and filled with concrete without tamping. The slump cone is lifted and the diameter of concrete in two perpendicular directions is measured, and the average of the two measured diameters is recorded. The higher the slump flow, the better the filling ability of concrete to fill formwork. This is usually the primary acceptance test method used on the jobsite and EFNARC (2002) requires a slump flow value between 650 – 800 mm.

For an additional measure of flowability, the time required for the concrete to spread to a diameter of 50 cm can be measured. This flow time is termed as T50 cm slump flow. A lower time indicates greater flow ability. This value of T50 generally ranges from 2-7 seconds. It is possible to assess the stability of concrete qualitatively after performing the slump flow test.

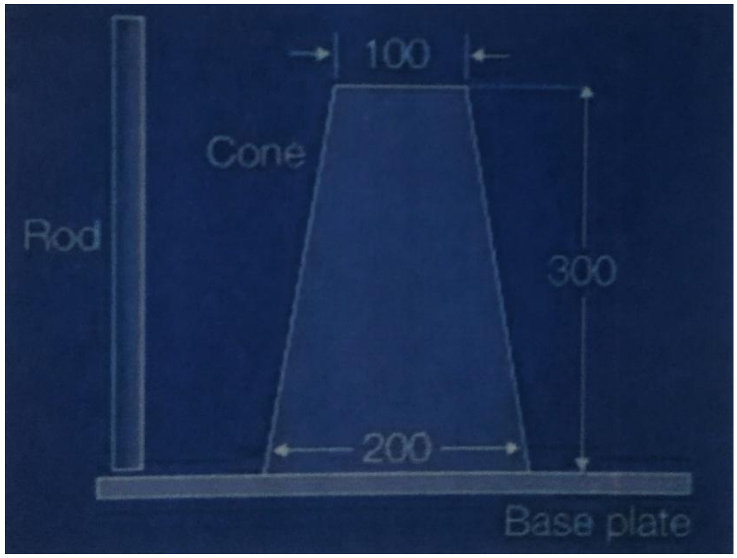

Figure 3.5(a): Slump Flow Apparatus

3.5.2 V- Funnel Test

V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20 mm. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. This test method is used to measure the flowability and dynamic stability of the SCC mixture. The funnel is filled with FASF SCC and the time required for the material to follow out is recorded. To measure segregation resistance, the V-funnel is refilled with concrete and allowed to sit for 5 minutes. The door is again opened and the flow time is recorded.

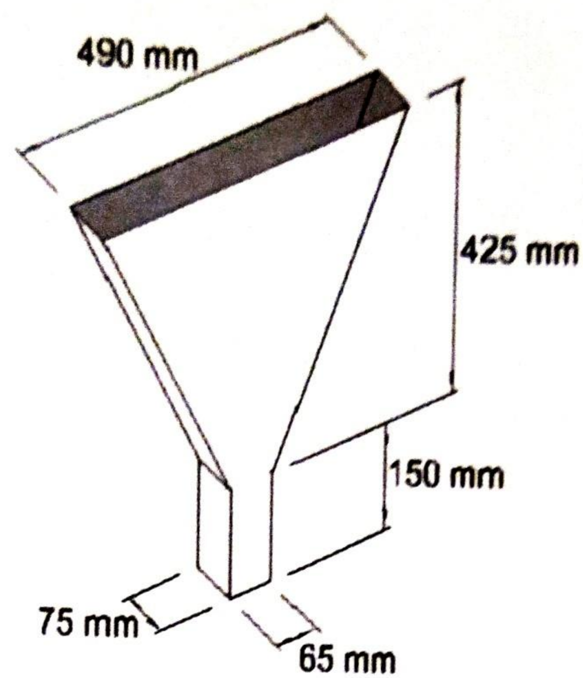

Fig. 3.6(a): V-Funnel Apparatus

3.5.3 J-Ring Test

The principle of the J ring test may be Japanese, but no references are known. The J ring test itself has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mm×25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals; in accordance with normal reinforcement considerations, 3x the maximum aggregate size must be appropriate. The diameter of ring in vertical bars is 300 mm and the height 100 mm.

The J ring can be used in conjunction with the slump flow, the Orimet test, or eventually even the V-funnel. These combinations test the flowing ability and the contribution of the J ring to the passing ability of the concrete. The Orimet time and/or slump flow spread are measured as usual to assess flow characteristics. The J ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

Figure 3.7: J-Ring test of FASFSCC

3.5.4 L-Box Test

The L-box value is the ratio of levels of concrete at each end of the box after the test is complete at each end of the box after the test is complete. The L-box consists of a “chimney” section and a “trough” section after the test is complete, the level of concrete in the chimney is recorded as H1, the level of concrete in the trough is recorded as H2. The L-box value (also referred to as the “L-box ratio”, “blocking value”, or “blocking ratio”) is simply H2/H1. Typical acceptable values for the L-box value are in the range of 0.8 to 1.0. If the concrete was perfectly level after the test is complete, the L-box value would be equal to 1.0. Conversely, if the concrete was too stiff to flow to the end of the trough the L-box value would be equal to zero.

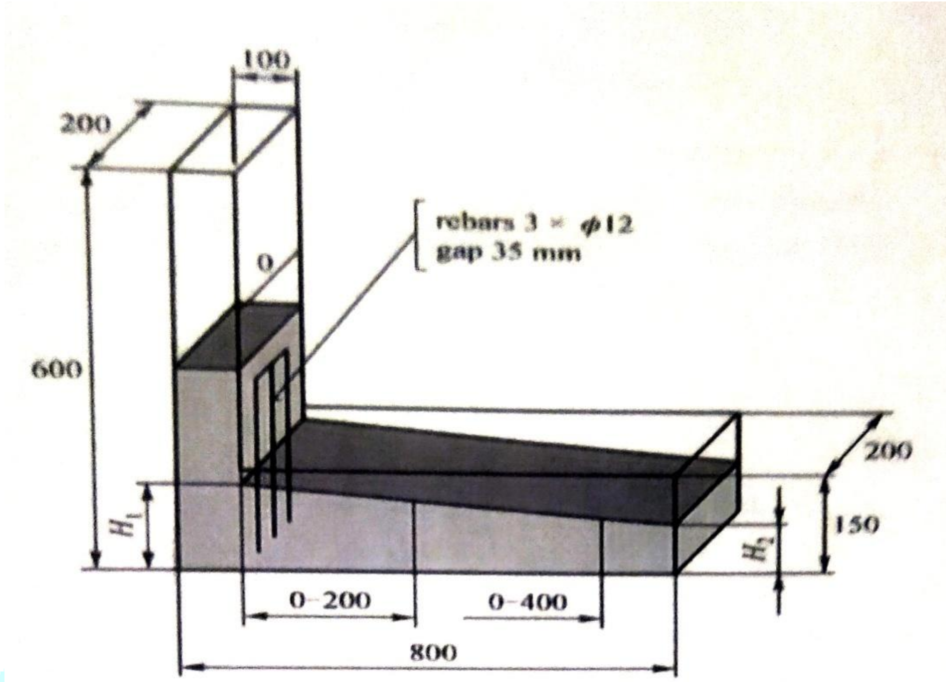

Figure 3.8(a): L-Box Test Apparatus

The time for concrete to reach points 20 cm (T20) and 40 cm (T40) down the horizontal portion of the box is recorded. After the concrete comes to rest in the apparatus, the heights of the concrete at the end of the horizontal portion, H2, and in the vertical section, H1, are measured. The blocking ratio, H2/H1, for most tests should be 0.80 to 0.85. Segregation resistance can be evaluated visually...

3.6 SPECIMEN DETAILS

The experimental program has been implemented by casting and testing of thirty fly ash silica fume SSC specimens containing of each volume fraction. These specimens have been tested for the analysis of test results after 28 days of normal water curing. Total number of cubes cast for the comparison of compressive strength results was thirty six including twelve cubes of each volume fraction of mineral along with twelve cubes of plain concrete. For testing purpose the average result of three specimens has been used for the analysis at each day of testing, i.e., after 7, 14, and 28 days after curing. A two letter nomenclature followed by the fibre content used in the mix, has been given to identify the different specimens. For example cube specimens are denoted by CU.

Table 3.7: Specimen Details

Type and Size of Specimen	Specimen Designation	Fiber Volume Fraction (%)	No. of Specimen Cast
Cubes (150 mm X 150 mm X 150mm)	CU 0.0	0	9
	CU 0.5	5	9
	CU 1.0	10	9
	CU 1.5	15	9
Total	CY 0.0	0	9
Cylinders (150 mm X 600 mm)	CY 0.5	5	9
	CY 1.0	10	9
	CY 1.5	15	9
Total			36
Beam 100 x 100 x 500 mm	BM 0.0	0	9
	BM 0.5	5	9
	BM 1.0	10	9
	BM 1.5	15	9
Total			36

The Table given above shows the total number of specimens cast during the whole project work.

CHAPTER IV EXPERIMENTAL RESULTS

4.1 GENERAL

Self-Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects and hence each mix has been tested by more than one test method for the different workability parameters. FASFSCC mix was designed and the workability tests have been done according to EFNARC standards, thereby stating concrete with mineral admixture also exhibit better resistance to crack formation. Hence, a mix design proportion 1:1.63:1.25 with water-cement ratio of 0.52 has been used as reference mix and 0%, 5%, 10% and 15% addition of fly ash and silica fume by weight of cement has been done, resulting in designed mix to check the properties of FASFSC. The compressive strength of cubes and axial load of column respectively have been determined at 7, 14 and 28 days of maturity. The test results have been presented in the tabular form in the subsequent sections and in each case a comparison has been made between the reference mix and the mixes with fibres.

4.2 WORKABILITY TEST RESULTS

The tests for fresh properties include the workability methods specified by EFNARC. The three essential distinct, though related properties that demonstrate the Self Compactability of SCC flowability, passing ability and segregation resistance. For this purpose four tests – Slump flow test, V-funnel test, L-box test, J-ring test have been conducted and variation in fresh state properties of concrete was observed. The effect of mineral admixture on the properties of SCC has been studied by adding 0%, 5%, 10% and 15% by volume of cement.

4.2.1 Slump Flow Test Results

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The time T50cm is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 500 mm. figure 4.1 shows the results of the slump flow of SFRSCC of varying fibre content. The values are noted and are tabulated in Table 4.1.

Table 4.1: Workability Results of FASF SCC

S. No.	SF Content (%)	Slump Flow (mm)	T50 Slump Flow (sec)	V-Funnel (sec)	J-Ring (mm)	L-Box (H2/H1)
1	00	680	3.0	8.0	15	0.86
2	05	675	3.0	9.0	17	0.83
3	10	650	4.0	9.0	18	0.82
4	15	630	5.0	10.0	20	0.80

Table 4.2: Acceptance Criteria for SCC Recommended by EFNARC (2002)

S. No.	Method	Unit	Typical range of values Minimum	Maximum
1	Slump flow test	mm	650	800
2	T50cm slump flow	Sec	2	5
3	V-funnel test	Sec	6	12
4	J-ring Height reduction	mm	0	20
5	J-Ring Flow reduction	mm	0	100
6	L-Box test	H2/H1	0.8	1.0

The figure 4.1(a) and 4.1(b) shows the slump flow test and T50 slump flow test results against fibre content

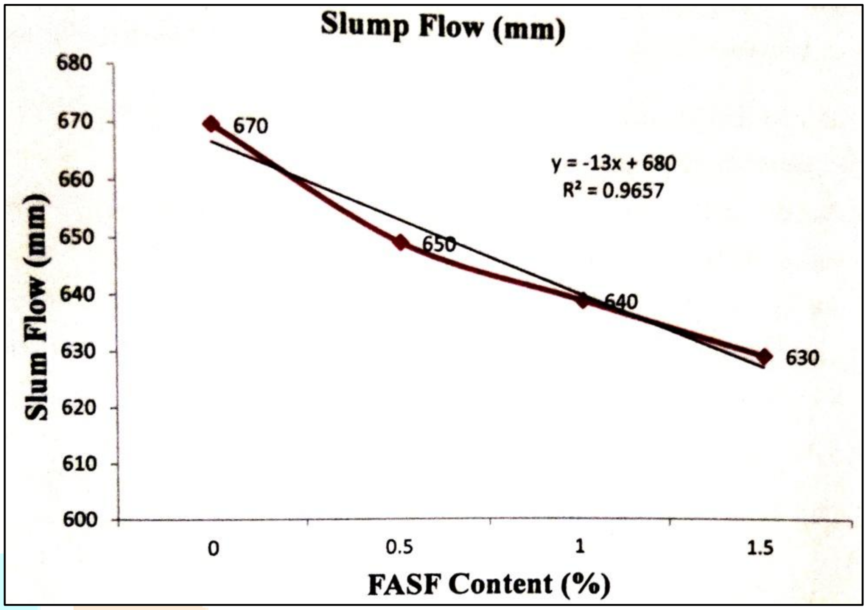

Figure 4.1(a): Slump Flow Test Results Against FASF Content

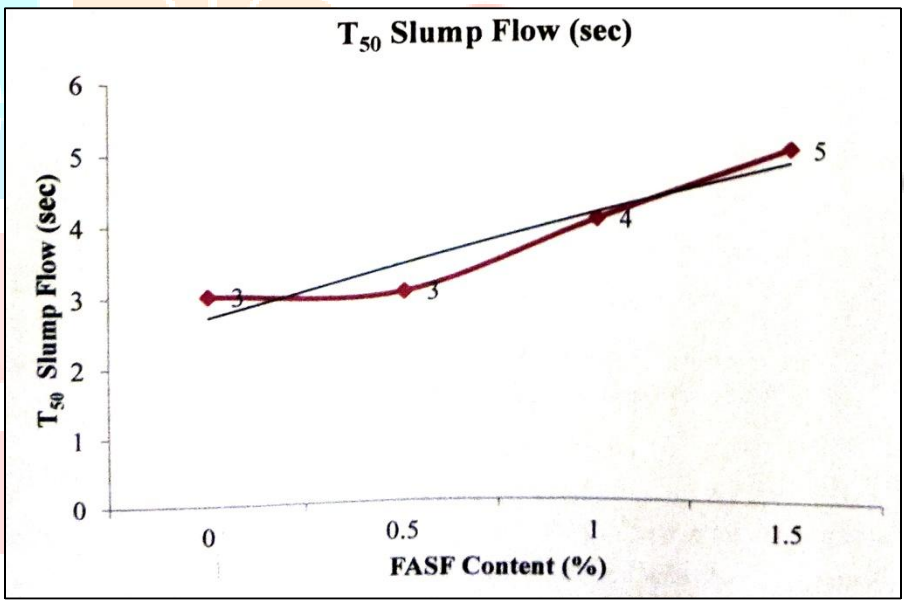

Figure 4.1(b): T50 Slump Flow Test Results Against FASF Content

4.2.3 V-Funnel Test Results

To assess the flowability and stability of freshly prepared concrete, all four mixes with different contents of steel fibers were tested by V-funnel test. The flowability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured.

The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus is measured. Further, T_5 min is also measured with V-funnel, which indicates the tendency for segregation, where in the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly. The results have been presented in Table 4.1 and figure 4.2. According to the results of test, the V-funnel flow time varies between 9 and 11 s.

V-Funnel (sec)

V-Funnel Results Graph

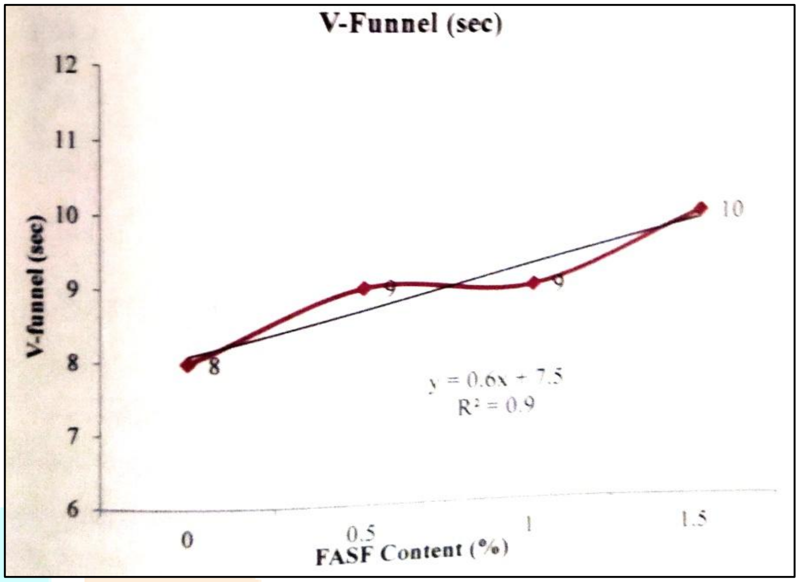

Figure 4.2: V- Funnel Test Results Against FASF Content

4.2.3 J-Ring Test Results

The J-Ring test (EFNARC 2002) extends common filling ability test methods to also characterize passing ability. The J-ring test device can be used with the slump flow test, the crinet test, or the V-funnel test.

While conducting this test, the slump cone is placed in the centre of the J-ring and filled with concrete. The cone is lifted slowly and the concrete is allowed to flow horizontally through the bars of J-Ring.

The difference in the horizontal spread without and with J-Ring is used to measure the passing ability. The results have been presented in Table 4.1 and figure 4.3. The graph below shows the results of J-Ring test for different fibre volume fractions.

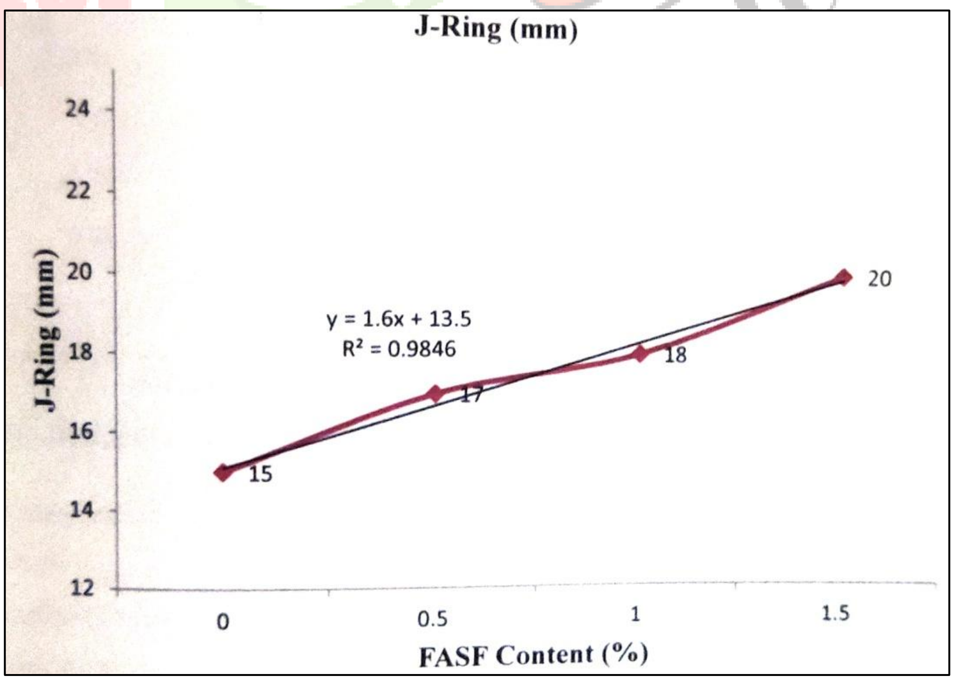

Figure 4.3: J-Ring Test Results Against FASF Content

4.2.4 L-Box Test Results

The L-Box test is used to check the filling and passing ability of SCC. The blocking ratio (H2/H1) of various SCC mixes is shown in figure 4.4. The blocking ratio should be between 0.8 and 1.0. While assessing the fresh concrete for passing ability, it is observed that all the four mixes pass through the bars of L-box very easily and no blockage is seen in any of the mixes. The results of L-box test show that, although the blocking ratio (H2/H1) gradually decreases with the increase in the quantity of fiber content, the ratio (H2/H1) for all the mixes is above 0.8, which is as per EFNARC standards. Following graph shows the results of the test conducted on various mixes.

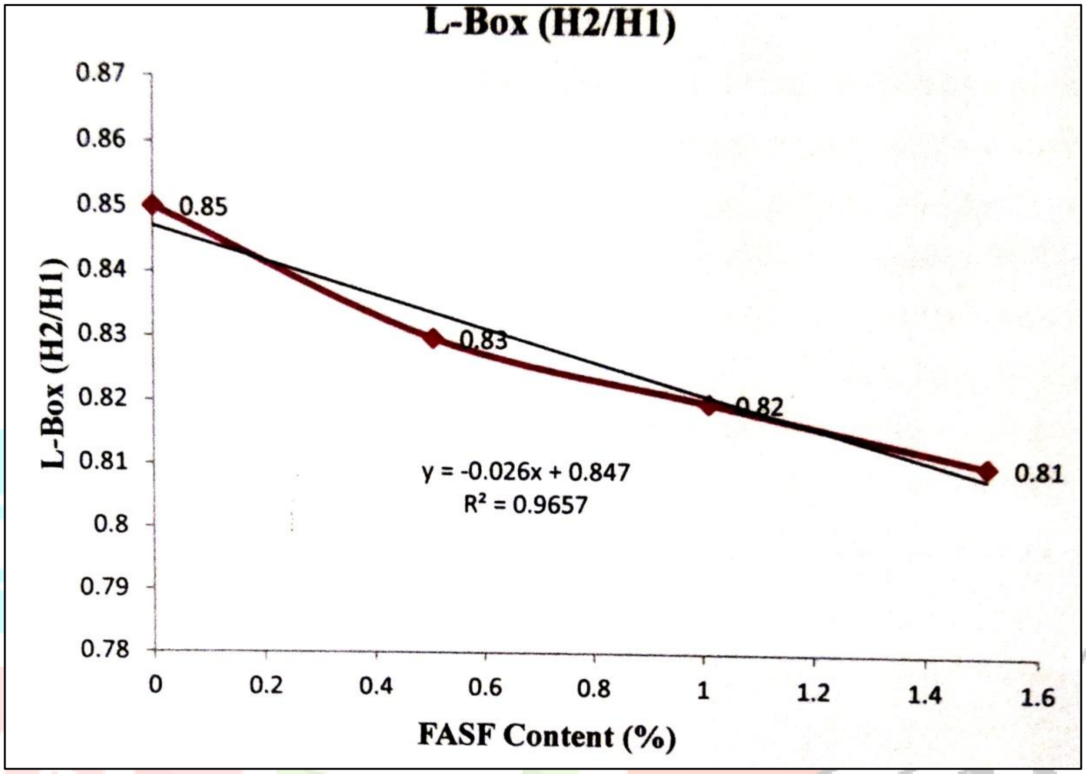

Figure 4.4: L-Box Blocking Ratio Against FASF Content

4.3 HARDENED STATE TEST RESULTS

The compressive strength is one of the most important properties of concrete in most structural applications. The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 28 days (fck). This concept assumes a normal distribution of the strengths of the samples of concrete. The compressive strength of SFRSCC is affected by a number of steel fiber factors including the shape, casting direction, and distribution as well as the property of interface between steel fiber and cement paste among others. The compressive strength increases with increase in the aspect ratio (L/D) of fiber and with decrease in the water-to-cementitious material ratio (w/c). SCC will typically have a slightly higher compressive strength when compared to a conventional concrete of similar w/c ratio. This is due to the improved interlock between the aggregate and the hardened paste. In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine.

4.3.1 Compressive Strength Test Results

The compressive strength test for the casted cubes of size 150mm x 150mm x 150mm will be done following the requirements of IS: S16-1959. Three numbers of specimen will be tested at the desired ages for each and every mix and type. The testing of the specimens will be carried out on a hydraulic compression testing machine of capacity 200T. After cleaning off the bearing surface of the testing machine the specimens will be placed in the machine in such a manner that the loads could be applied to opposite sides of cubes as cast. The axis of the specimen will be kept carefully aligned with the centre of thrust of the spherically seated platen. figure 4.5 shows the compression testing machine (200 Tons) used in the experimental programme for testing the compressive strength of cube specimen.

200 T Compression Strength Testing machine

Figure 4.5: 200 T Compression Strength Testing machine

The average value of compressive strength for four specimens of each fibre content is given in

Table 4.3 and the corresponding graph is given in figure 4.6.

Table 4.3 Hardened State Test Results

Mix	% FASF	Days	Compressive Strength (Mpa)
M-00	FA15SF00	7	26.3
		14	34.8
		28	37.5
M-05	FA15SF05	7	27.1
		14	35.5
		28	38.2
M-10	FA15SF10	7	28.4
		14	36.3
		28	39.0
M-15	FA15SF15	7	27.9
		14	35.8
		28	38.8

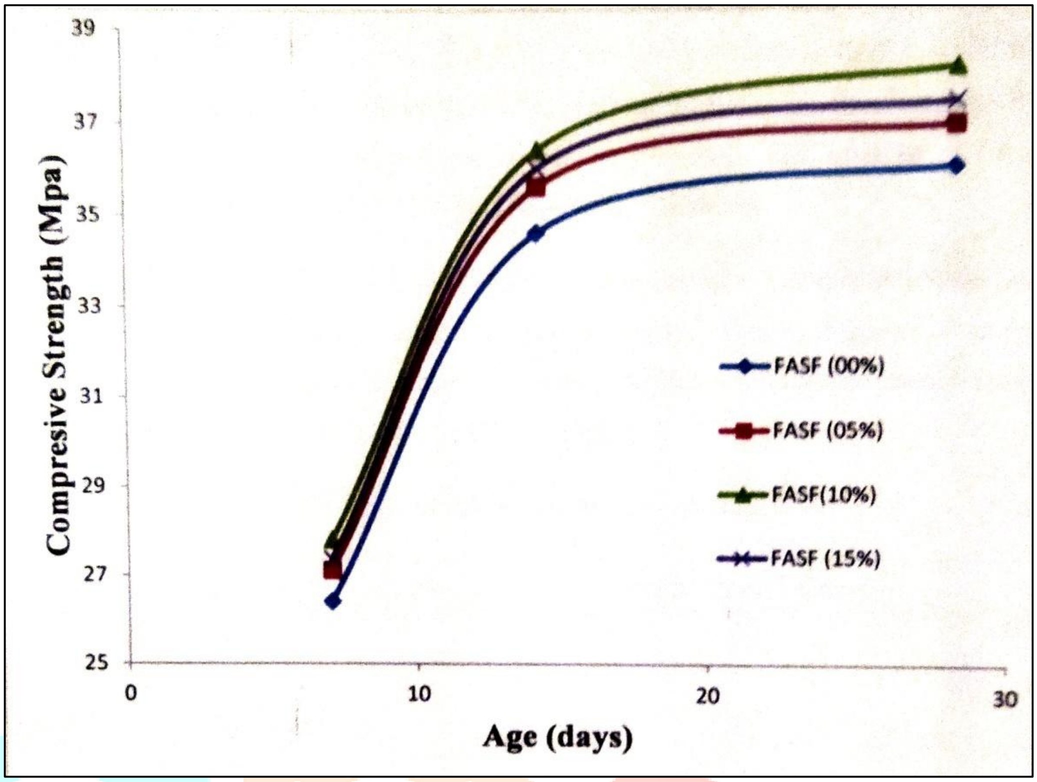

Figure 4.6: Variation of compressive strength of FASFSCC with age of specimen

4.3.2 Split Tensile Strength

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete.

Split-tensile strength has been conducted on cylinder specimens of size 150 mm in dia. by 300 mm height. The magnitude of this tensile stress *osp* (acting in a direction perpendicular to the line of action of applied loading) is given by the formula (IS: 5816-1970):

osp = 2P/ndl = 0.637 P/dl

Within the practical limitations imposed on volume and aspect ratio (length/diameter) of fibres for the case of mixing, there is a modest increase in the split tensile strength due to the fibre reinforcement, but more substantial increase in the toughness. Split cylinder test is performed to determine the indirect tensile strength of the fibre concrete. But there is a limit unto which volume fraction of fibres can be increased. The addition of FASF generally increases the tensile strength by 5 percent to 15 percent.

Split-tensile strength test was performed on the cylinder having a diameter of 150mm and 300mm height. The test was done after 7, 28, 56 and 90 days of curing. Figure 4.13 shows the experiment being conducted in the laboratory. The test results are presented in the Table 4.4 and its corresponding relation in Figure 4.14.

Table 4.4: split tensile strength Test Results

Mix	% FASF	Days	Tensile strength (Mpa)
M-00	FA15SF 00	7	2.52
		14	3.37
		28	3.65
M-05	FA15SF 05	7	2.65
		14	3.51
		28	3.86
M-10	FA15SF 10	7	2.73
		14	3.65
		28	4.17
M-15	FA15SF15	7	2.66
		14	3.55
		28	3.93

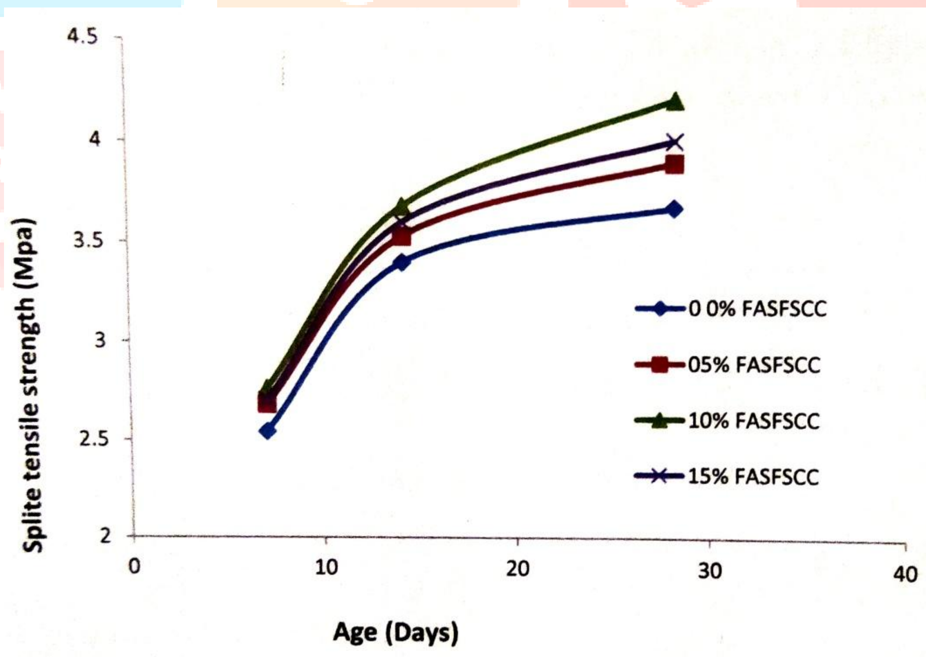

Figure 4.7 Relation Between split tensile strength of FASFSCC with age of specimen cured in normal water

4.3.3 Flexural Strength

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three-point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The increase in the flexural strength (characterized by the modulus of rupture) for mortars and concrete is of the order of 25 percent for the values of

Vf/id from 40 to 120 (practical limit from workability consideration). Here, Vf and id are the optimum fiber parameters, Vf denoting the volume fraction and id denoting the aspect ratio. Flexural strength has been conducted.

On beam specimens of size 100mm x 100mm x 500mm. It has been studied that change in flexural strength marginally. The addition of steel fibre increases the flexural strength, as it has higher modulus of elasticity with respect to the cement matrix. Studies reported that compared to steel reinforced cement concrete, polymer concrete exhibits higher strength, higher ductility and higher deflection at failure.

Flexural strength test was performed on the beam size of 100 x 100 x 500mm. The test was done after 7, 14 and 28 days of curing. The figure below shows the flexural strength of beam specimen being conducted in the laboratory.

Table 4.5: Flexural Strength of FASFSCC

Mix	% Fibre	Days	Flexural strength (Mpa)
M-00	FA15SF 00	7	1.84
		14	2.58
		28	3.53
M-05	FA15SF 05	7	1.99
		14	2.79
		28	3.65
M-10	FA15SF 10	7	2.30
		14	3.03
		28	3.95
M-15	FA15SF 15	7	2.17
		14	2.91
		28	3.80

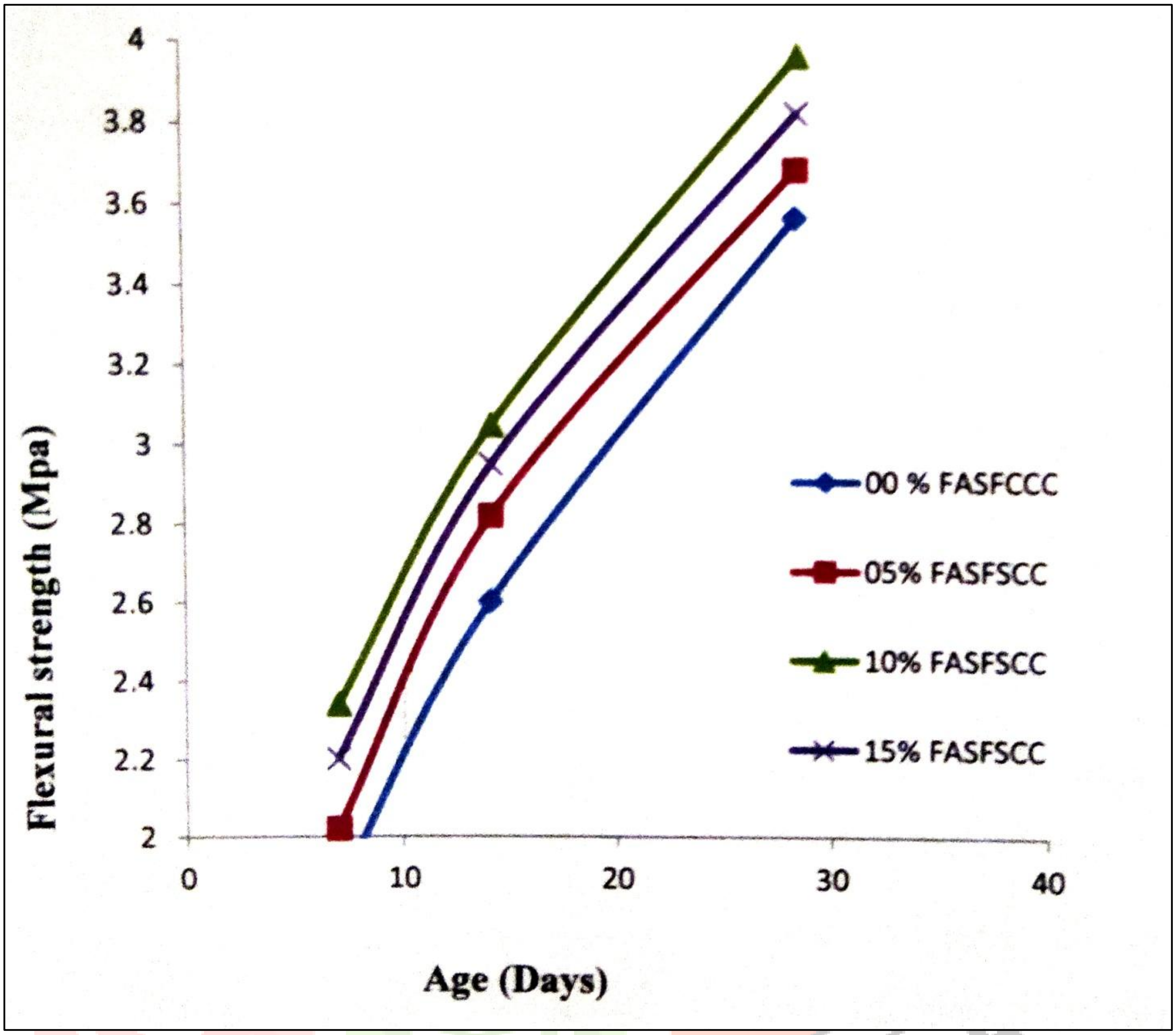

Figure 4.8 Relation between flexural strength of SFRSCC with age of specimen cured in normal water

CHAPTER V TEST RESULTS AND DISCUSSION

5.1 INTRODUCTION

This chapter contains the discussion of the test results related to the effect of fly ash and silica fume on the fresh self compacting concrete and hardened properties of FASF SCC such as compressive strength, split tensile strength, flexural strength. All test results tabulated in the previous chapter through Tables 4.1 to 4.5 and the graphs plotted in figures 4.1 to 4.8 have been discussed in the subsequent sections.

5.2 TESTS ON FRESH SELF COMPACTING CONCRETE

The results of fresh properties of various FASF SCC mixes with the different contents of mineral admixture are presented in Table 4.1. From the results obtained it can be said that the addition of steel fibres to self-compacting concrete affects its fresh state properties.

The results of slump flow test are shown in figure 4.1(a). Test results indicate that, except for mix F-1.5, slump flow for all the mixes is within the EFNARC range of 650-800 mm. A maximum slump flow value of 680 mm is achieved for the control mix F-0.0. With the increase in the FASF content, the flow of various FASF SCC mixes decrease. This may be attributed to the very fine particle size and the increased surface area of fly ash.

The slump flow time for concrete to reach 50 cm diameter (T50cm slump flow) was also recorded during the test. figure 4.1(b) illustrates the results of T50cm slump flow. It can be seen that all the four mixes qualify the permissible limits (2-5 sec) given by EFNARC. T50 cm slump flow varies between 3 and 5 sec. The lowest slump flow time of 3 sec is recorded for the control mix containing 0% fly ash and silica fume. An increase in the quantity of steel fibers leads to the increase in T50 cm time. This may be due to the increasing paste volume with admixture.

To assess the flowability and stability of freshly prepared concrete, all the four mixes with different contents of steel fibers were tested by V-funnel test. The V-funnel flow time values obtained from the test are shown in figure 4.2. According to the results of test, the V-funnel flow time varies between 9 and 11 sec. It can be seen that all the concrete mixtures meet the requirements of allowable flow time. The minimum flow time of 8 sec is recorded for the control mix containing 0.0% fly ash and silica fume increase in fly ash and silica fume content the fluidity of concrete decreases. Consequently the V-funnel flow time increases. The same reasons and mechanism mentioned for slump flow test results are also commanding the explanations for the results of V-funnel test.

The J-Ring test allows the measuring of the difference of heights in the inner layer and the outer layer of the concrete after the slump cone is lifted. Here the difference is plotted against the fibre content and is presented in figure 4.3. From the graph it can be said that there is a steady increase in the difference of heights as the fibre factor increases. In other words, as the number of fibre increases the flow of concrete on the base plate decreases.

The L-Box test allows measuring the blocking ratio of SCC. Here the blocking ratio is plotted against fibre content and is given in figure 4.4. The blocking ratio (H2/H1) of various SFRSCC mixes is shown in Table 4.1. The blocking ratio should be between 0.8 and 1.0. While assessing the fresh concrete for passing ability, it is observed that all the four mixes pass through the bars of L-box very easily and no blockage is seen in any of the mixes. It can also be said that as the length of fibres increases the blocking ratio decreases. The results of L-box test show that, although the blocking ratio (H2/H1) gradually decreases with the increase in the fly ash and silica fume content, the ratio (H2/H1) for all the mixes is above 0.8 which is as per EFNARC standards.

5.3 TESTS ON HARDENED PROPERTIES

5.3.1 Compressive Strength

Concrete without steel fibers when tested for compressive strength should yield the strength of 30 MPa after 7, 14, and 28 days of normal curing. The results of the compressive strength of SFRSCC are given in Table 4.3. From the table it is clear that due to the addition of fly ash and silica fume to normal strength Concrete i.e. 0.5%, there is a gradual rise in the compressive strength of Concrete by 3.04% at 7 days of maturity, 2.01% at 14 days of maturity, 1.86% for 28 days of maturity. When 10% of FASF are added to concrete, their increase in strength at 7 days is 4.10%, 4.31% at 14 days, 4.0% at 28 days of maturity. Similarly when 15% of fly ash and silica fume are added to concrete, their increase in strength at 7 days is 6.08%, 2.87% at 14 days, 3.46% at 28 days of maturity.

From the graph (Figure 4.6), it is obvious that there is a steady increase in the compressive strength of normal strength concrete with respect to the addition of fly ash and silica fume.

It also indicates that with increase in volume fractions, the compressive strength of normal strength concrete increases up to volume fraction of 10%.

5.3.2 Split-Tensile Strength

One of the main reasons for the addition of fly ash and silica fume to concrete is to increase its tensile strength. Hence FASF were added to FASFSCC mix and the results obtained are given in Table 4.4. It can be noted from the table that due to the addition of fly ash and silica fume to FASFSCC i.e. 0.5%, there is rise in the split-tensile strength of SCC by 4% for 7 days of curing, 3% for 14 days of curing plus the 7 days result, 3% for 28 days of curing plus the base result. Due to the addition of fly ash and silica fume to SCC i.e. 10%, there is rise in the split tensile strength of SCC by 7%, 4.5%, and 4% for 7, 14, and 28 days of curing respectively. When 15% of fly ash and silica fume are added to the mix there is a marginal decrease in the split-tensile strength of SCC by 9%, 7%, and 7.5% for 7, 14, and 28 days of curing respectively. The graph plotted on the basis of the results obtained (Figure 4.7) showed that the split tensile strength increases more rapidly for 0.5% addition of fly ash and silica fume to the mix M-00 upto the addition of 10%. So optimum dose of fly ash and silica fume is 10%.

5.3.3 Flexural Strength results

When fly ash and silica fume are added to concrete, it increases the strength or ductility of the concrete. Also it enhances the tensile properties of concrete. From table 4.5, it can be said that when 05% fly ash and silica fume are added to concrete, the percentage of increase in flexural strength as compared to conventional SCC is 5%, 10%, and 15% for 7, 14, and 28 days of curing respectively. When 1% steel fibres are added to SCC, there is an increase in flexural strength of about 5%, 4%, and 3% for 7, 14, and 28 days of curing respectively. When steel fibres are added in excess, i.e., 15% to SCC there is slight decrease in the flexural strength of SCC as compared to conventional SCC. It decreases by 8%, 6%, and 6% for 7 days, 14 days, and 28 days of curing. From the graph plotted (Figure 4.8), it can be seen that upon the addition of steel fibres to SCC mix M-00 by 05%, the 28 days flexural strength increases. The optimum dosage found to be suitable was 10%.

CHAPTER VI SUMMARY AND CONCLUSIONS

6.1 GENERAL

FASFCC is an innovative type of concrete, which combines the advantages and extends the possibilities of both SCC and FASFCC. This thesis summarises various studies on the characteristics of FASFCC in the fresh and the hardened state. It contains experiments that predict the performance of the mixture compositions and offer design tools that decrease the number of laboratory experiments required to obtain an optimised FASFCC.

The thesis consists of three distinguished parts. First part comprises the experimental parameter studies have been carried out to determine the effect of the addition of the steel fibers on the characteristics of SCC in the fresh state. Optimised FASFCC mixtures have been tested, which were based on SCC mixtures without fly ash and silica fume. The applied contents of the fly ash and silica fume have been chosen close to the maximum admixture content, which are determined by varying the fly ash and silica fume content in defined steps. Additionally, studies have been performed on the characteristics of the components of FASFCC. The experiments consider three key characteristics of FASFCC: filling ability, passing ability and resistance to segregation.

This study on fly ash and silica fume self compacting concrete was taken up with the objective of improving the strength property. FASFCC is useful when a large amount of energy has to be absorbed where a high tensile strength and reduced cracking are desirable or even when conventional reinforcement cannot be placed because of the shape of the members. Fly ash and silica fume content concrete is improving the impact strength of concrete, limit the crack growth, and lead to a greater strain capacity of the composite material because they provide strength after the cement paste matrix has cracked. In the present work, cube specimens cured and tested for compressive strength of FASFCC at 7, 14, and 28 days of maturity, and behaviour of FASFCC have been discussed rationally and accordingly suitable conclusions have been arrived at. The conclusions drawn from the experimental study are as under.

6.2 CONCLUSIONS

Based on the results obtained from the investigation and after rational discussion, the following conclusions have been drawn on hardened properties of FASFSCC. The workability results have been found to be satisfactorily acceptable according to EFNARC standards. FASFSCC with high workability and good slump retention can be obtained for a silica fume content up to 10% for the tested.

- SCC containing the specified quantity of different mineral and chemical admixtures as proposed in this investigation has been found to be complying with all the workability requirements as per EFNARC (2002). It is found to have good consistency and workability for all the four mixes at a constant w/p ratio of 0.52 and constant superplasticizer dosage of 1.3% of weight of cement.
- Comparison of workability test results of different combinations of mixes with the reference mix shows that with increase in the fly ash and silica fume content in the mixes, the mix becomes dense and hence less workable.
- There is considerable increase in compressive strength, i.e. upto 4.31% for 10% silica fume content. It clearly indicates that compressive strength at all ages increases in the addition of fly ash and silica fume up to 10%.
- The compressive strength increased due to the addition of fibre for the mix M-00. Therefore, when a structure is expected to be under compression, a fibre addition in mix M-00 would not prove to be safe under any circumstances upto the addition of 10%.
- Split-tensile strength of FASFSCC is higher than those of SCC for the same cube compressive strength. This effect is attributed to the higher powder content and the addition of steel fibres. It increases by 3.17% upon steel fibre addition of 0.5% by weight of concrete in mix M-00. The addition of 10% silica fume in concrete increases the split tensile strength by 4.37% in the mix and with the addition of 15% of silica fume to the concrete, the split-tensile strength starts to decrease. It has been observed that up to the addition of 10% of silica fume to the concrete, the split tensile strength of concrete increases constantly.
- Significantly the flexural strength concrete of the mix with 05% and 10% of silica fume addition increases the flexural strength up to a marginal amount by 1.79%, 2.35% and beyond which it starts to decrease at a constant rate. Thus, it can be stated that the addition of silica fume to concrete increases the hardened properties of concrete.

6.3 SCOPE OF THE FUTURE WORK

The application of SCC facilitates the production process and its conditions, since vibration is eliminated. The benefits of SCC also apply for FASFSCC in case the effect of key characteristics filling ability, passing ability and segregation resistance is taken into account. Increases in compressive strength were observed in the experiment by the addition of Silica fumes. Further studies can be made by varying the percentage of Silica fume in the mix. Fibres reduce the cracks during plastic and hardening stage. This property can be studied for further research. The effect of Silica fume varies with different mix proportions. An extensive study on this effect with different mix proportions if done may prove beneficial by reducing the decoration and abrasion of structures. concrete can be advantageously used in the energy dissipating blocks owing to its energy absorption nature. A research work can be made in this regard, so that it can be used in explosive loading devices. Only two types of mineral admixture was used in this study (fly ash and silica fume).

In this study the increase in compressive strength, and higher load carrying capacity with higher ductility of column were observed in this research work by the addition of fly ash and silica fume to the M30 designed concrete. Further studies can be made by varying the percentage of fly ash and silica fume in the design mix. These properties can be studied for further research with different aspect ratio of different admixture materials.

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