IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

EXPERIMENTAL INVESTIGATION ON MECHANICAL STRENGTH OF EMPTY FRUIT BUNCH FIBER REINFORCED SCC WITH PARTIAL REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG

A PROJECT REPORT

Submitted by

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to

the APJ Abdul Kalam Technological University

in Partial Fulfilment of the Requirements for the Award of the Degreeof

Master of Technologyin

Structural Engineering

DEPARTMENT OF CIVIL ENGINEERINGUNIVERSAL ENGINEERING COLLEGE

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JULY, 2023

DECLARATION

I hereby, declare that the project report entitled, "**EXPERIMENTAL INVESTIGATION ON EMPTY FRUIT BUNCH FIBER REINFORCED SCC WITH PARTIAL REPLACEMET OF FINE AGGREGATE WITH COPPER SLAG"**, submitted for partial fulfillment of the requirements for the award of degree in Master of Technology in Structural Engineering, APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under the supervision of Mrs. Chithira Krishnakumar. This submission represents my ideas in my own words and where the ideas or words of others have also been included. I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Vallivattom PRANAV V

DEPARTMENT OF CIVIL ENGINEERING UNIVERSAL ENGINEERING COLLEGE, VALLIVATTOM

CERTIFICATE

This is to certify that the report entitled **"EXPERIMENTAL INVESTIGATION ON EMPTY FRUIT BUNCH REINFORCED SCC WITH PARTIAL REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG"** submitted by **PRANAV V.** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Structural Engineering, Department of Civil Engineering is a bonafide record of the project work carried out by him under my guidance and supervision. This report in any form has notbeen submitted to any other University or Institute for any purpose.

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ACKNOWLEDGEMENT

First and foremost, I would like to thank God almighty for giving me all the grace, blessings and spirit to perform my project work successfully.

I owe my gratitude to my Guide & P.G. Coordinator, **Ms. Chithira Krishnakumar**, Assistant Professor, Department of Civil Engineering, Universal Engineering College, Vallivattom, who took keen interest in my thesis topic and guided me all along. I have fully benefited from her valuable guidance and constant encouragement at every step of this work. Her commitment to excellence, together with her excellent knowledge, has been essential for the accomplishment of this work.

I owe my deep gratitude to my Project Coordinator, **Ms. Anima P.**, Assosiate Professor, Department of Civil Engineering, Universal Engineering College, Vallivattom, who took keen interest in my thesis topic and guided me all along. I have fully benefited from his valuable guidance and constant encouragement at every step of this work. His commitment to excellence, together with his excellent knowledge, has been essential for the accomplishment of this work.

I hereby express my sincere thanks to **Dr. Harinarayan N.H.**, Head of the CivilEngineering Department for allowing me to conduct the project on the topic **"EXPERIMENTAL INVESTIGATION ON EMPTY FRUIT BUNCH FIBER REINFORCED SCC WITH PARTIAL REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG"**.

I also extend my gratitude to beloved Principal**, Dr. Jose K. Jacob,** for providing excellent library and computer facilities which have been valuable in the completion of Project. Gracious gratitude to all the faculty of the Department of Civil Engineering for their valuable advice and encouragement.

Finally, an honorable mention goes to my family and friends for their wholehearted support that helps greatly in completing my project.

PRANAV V.

ABSTRACT

Self-compacting concrete (SCC) has many benefits in terms of production and placement compared to traditional concrete namely, elimination of external or internal vibration for compaction, better flowability, workability and pumpability, as well as increased bonding with congested reinforcement. Moreover, the placement of SCC is faster and requires less labour. The appearance (surface finish), mechanical performance and durability of SCC can be considerably better than traditional concrete. Natural fiber-reinforced polymer composite materials have emerged in a wide spectrum of area of the polymer science. The composite produced from these types of materials are low density, low cost, comparable specific properties, and most importantly they are environmental friendly. The composite materials produced from oil palm fibers and commercially available polymers have offered some specific properties that can be comparable to conventional synthetic fiber composite materials. However, these properties are greatly dependent on the compatibility of oil palm fibers and matrix phase with moisture absorption as one of the critical issues that becomes the drawbacks of the oil palm fiber polymer composite materials. Apparently, it greatly affects the physical as well as mechanical properties of the composite materials. Combination of copper slag as fine aggregate in cement mortars, normal concrete and also as aggregates (coarse) in concrete (high strength). As fine aggregate in cement mortar, copper slag provides good interlocking leading to better volumetric and mechanical quality of different mixes. It was reported that about 50% substitution of copper slag in cement mortar increased the compressing strength highly, slightly increased the density and significantly increased the workability. But the addition of higher amount of copper slag resulted in the decrease of strength due to free H2O content increase in the mixture

Keyword: *Self Compacting Concrete, Copper slag, Empty fruit bunch fiber.*

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ABBERIVATIONS

SCC	-	Self Compacting Concrete
CS	-	Copper Slag
EFBF	-	Empty Fruit Bunch Fiber
OPC	-	Ordinary Portland Cement
VMA	-	Viscosity Modifying Agent
CM		Control Mix

CHAPTER 1 INTRODUCTION

1.1 GENERAL

Self compacting concrete (SCC) can be defined as fresh concrete that flows under its own weight and does not require external vibration to undergo compaction. It is used in the construction where it is hard to use vibrators for consolidation of concrete. Filling and passing ability, segregation resistance is the properties of self compacting concrete. SCC possesses superior flow ability in its fresh state that performs self compaction and material consolidation without segregation issues.

Self-compacting concrete (SCC) has many benefits in terms of production and placement compared to traditional concrete namely, elimination of external or internal vibration for compaction, better flowability, workability and pumpability, as well as increased bonding with congested reinforcement. Moreover, the placement of SCC is faster and requires less labour. The appearance (surface finish), mechanical performance and durability of SCC can be considerably better than traditional concrete. However, the methods of production, placement, quality control and finishing are essential for SCC. Constructability issues may arise for specifiers and contractors if related standards, guidelines or practices are not appropriately followed for production and placement. Self-compacting concrete is less tolerant to abrupt changes in aggregate moisture content, chemical admixtures and water content. The type of concrete mixer, transport time and the methods of concrete placement and finishing can affect the properties of SCC. Therefore, robust quality control measures must be in place during the production and placement of SCC. The excellent flowability of SCC compared to traditional concrete makes pumping the best method of placement. However, there is a high chance of air entrainment due to a higher flow rate, which can result in bugholes and segregation. Normally SCC has less surface imperfections compared to traditional concrete, but it would be susceptible to bugholes, honeycombing and cracking if guidelines of production and placement were not followed appropriately.

1.2 EMPTY FRUIT BUNCH FIBER

According to environmental concerns and financial problems, natural fibers have become interesting and fascinating nowadays to be used as an industrial material and structural material for rehabilitating of structures. Oil palm empty fruit bunch fiber (OPF) is a natural fiber which is found a lot in tropical areas. Oil palm fibers are also one of the natural fibers available abundantly in many countries and utilized by many researchers as reinforcement in cement and polymer composites. Oil palm, whose botanical name is Elaeis guineensis, is a commonly observed commercial oil crop in tropical regions of West Africa and Southeast Asia The construction industry has grown enormously over the last few decades. Concrete has been the key component in most construction works. Concrete is very good in compression but the weak tensile properties have made an urge to improve its tensile properties with different reinforcement materials. The reinforced concrete has more tensile strength compared to non-reinforced concrete. There are several types of fibers used in reinforced concrete. The Usage of natural fibers in concrete has not only improved the tensile properties but also has a positive impact on Environment. There are many varieties of natural fibers available in the market. This state-of-the-art review represents the potential of oil palm empty fruit bunch (OPEFB) fibers as reinforcement. Several researchers have used OPEFB fibers as reinforcement in composite materials in the construction industry

Fig 1.1 Empty Fruit Bunch Fiber

Fruit

Fig 1.1 Empty Bunch Fiber

1.3 COPPER SLAG

Copper slag, which is the waste material produced in the extraction process of copper metal in refinery plants, has low cost, and its application as a fine aggregate in concrete production reaps many environmental benefits, such as waste recycling, and solves disposal problems. Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granule. Copper slag can be used in concrete production as a partial replacement for sand.

Copper slag is used as a building material, formed into blocks. Such use was common in areas where smelting was done, including St Helens and Cornwall[2] in England. In Sweden (Skellefteå region) fumed and settled granulated copper slag from the Boliden copper smelter is used as road-construction material. The granulated slag (<3 mm size fraction) has both insulating and drainage properties which are usable to avoid ground frost in winter which in turn prevents pavement cracks. The usage of this slag reduces the usage of primary materials as well as reduces the construction depth which in turn reduces energy demand in building. Due to the same reasons the granulated slag is usable as a filler and insulating material in house foundations in a cold climate. Numerous houses in the same region are built with a slag insulated foundation. Copper slag being a waste product needs to be addressed. Dumping or disposal of these in huge quantities is regarded as environmental pollution and considerable research has been undertaken on the subject worldwide. Copper slag can be utilized as fine aggregate in cement mortars, normal concrete and also as aggregates (coarse) in concrete (high strength).

As fine aggregate in cement mortar, copper slag provides good interlocking leading to better volumetric and mechanical quality of different mixes. It was reported that about 50% substitution of copper slag in cement mortar increased the compressing strength highly, slightly increased the density and significantly increased the workability. But the addition of higher amount of copper slag resulted in the decrease of strength due to free H2O content increase in the mixture. Addition of copper slag in the concrete also showed an improvement in the flexural strength of the concrete. So as a waste material it can be widely used as a fine aggregate in concrete to improve the compressional tensile and flexural strength in concrete

Fig. 1.2 Copper Slag

CHAPTER 2 LITERATURE REVIEW

2.1 GENERAL

The section presents the experimental studies which have been conducted on concrete using copper slag and EFB. This chapter contains a brief account of the published literature related to the use of copper slag and empty fruit bunch fiber.

Panagalla Rama Rao et al. (2022) they discuss the nature and properties of empty fruit bunch fibers as well as their cement composites in a detailed way. The present state-of-the-art report will help researchers work toward cement composites. Oil palm empty fruit bunch (OPEFB) fibers are obtained from the empty fruit bunches by retting after the separation of fruits for oil production Empty fruit bunches are the significant source of lignocellulose biomass available at the palm oil mills. EFBF was added 1% along with the M 25 grade concrete. The result shows that the compressive strength are high in the mix of 1% EFBF.

G. Rama Krishna et al. (2022) studied the structural properties and classifications empty fruit bunch fiber. In consist of 20–25 % of stalk and 75 to 80 % of spikelet. Traditionally, the OPEFB has been used as fuel for boilers, and their ash is supplied as fertilizer. The addition of these fiber spikelets in various ratios made the concrete more capable to bear flexural load.

Adithya Kumar Tiway et al. (2022) studied about the left over waste which is causing a potential harm to the environment. The fruit bunches are used in various applications such as bio-composites, bio sugar, compost, fuel, and cellulose derivatives. Fewer applications are not getting explored because presence of a waxy layer and silica bodies on the surface of OPEFB, resulting in poor bonding between the fiber and matrix. However, some researchers clearly explained the physical properties, mechanical properties, and chemical composition of OPEFB fiber. Various authors determine the mechanical properties of the OPEFB fiber. The tensile strength is the basic mechanical parameter that is associated with the other parameters.

S Khalifa, Al Jabbari et al. (2020) studied about surface treatment may cause brittleness of fiber which results in lower strain values. The mechanical properties of OPEFB fiber reported by various authors are different from each other. This variation is due to different factors such as the age of the parent plants, age of the fiber after extraction, surface condition of fiber, i.e., cell wall peel off, skin damage, surface treatments adopted, gauge length and pressure variation in grips while testing. The thermal degradation of OPEFB happens in three stages namely loss of moisture at 100 °C, degradation of cellulose and hemicellulose at 195 °C to 360 °C, and oxidation at higher temperatures.

Sethuraman Muthuswami et al. (2019) The compressive strength of cement composite is decreased at higher fiber content i.e. the fiber content more than 5 % by weight of cement at the fiber content of 1.0 % by weight of and at the fiber content of 10 % by weight of cement The compressive strength of the cement mortar with 0.5 % (by weight of binder) of fiber content is 4.2 % more than the control mix at 28 days, and for the higher range of fiber content, such as 1 % (by weight of binder) and 1.5 % (by weight of binder), a reduction in strength is observed. It is the higher volume of fiber that creates more pores which may lead to early failure. Mohamed and Ismail (2008) reported that the compressive strength of the concrete is increasing with increasing fiber content from 0.25 % to 0.50 % (by weight of cement) and fiber length from 2.5 cm to 5 cm. Around 40 % of compressive strength grows at seven days for 5 cm length and 0.25 % fiber content by weight of cement. The maximum compressive strength was found at 90 days for 5 cm length and 0.5 % fiber content by weight of cement and reported that the compressive strength of the concrete cubes is increased with fiber content at various ages and also mentioned that they have not arrived at optimum dosage among 5 kg/m3; 10 kg/m3, and 15 kg/m3.

Mokhtar et al. (2017) studied the performance of cement block reinforced with OPEFB in dry stock masonry under different eccentr77ic conditions. The compressive strength decreases with eccentricity. The addition of OPEFB fiber does not improve the compressive strength but changes the mode of failure under eccentric loading. The split strength at 28 days is more for 1 % fiber content compared to 0.5 % and 1.5 % fiber content by weight of cement, and at 7 days, the control mix is having higher strength than the reinforced one (Abd. Aziz et al., 2014). The insufficient bond strength between fiber and matrix may result in low tensile strength. The tensile strength of the concrete increases with an increase in fiber length and fiber cont distribution of fiber will absorb more stress and break at a higher loads.

Zangh P et al. (2017) studied the flexural strength improved by about 19 % at a 0.52 water-cement ratio and 0.5 % fiber content by weight of cement. The addition of OPEFB fibers improves both flexural strength and ductility for 0.5 % and 1 % fiber contents by weight of cement. In the case of 1.5 % fibers by weight of cement, only ductility improved . The flexural strength of both oil palm and coir fiber reinforced composites is decreased with an increase in fiber content. The flexural strength of both oil palm and coir fiber reinforced mixes is less than the control mix.

Marvila M et al. (2017) investigated that the flexural strength of OPEFB fiber composites is slightly less than the coir fiber composites. At 10–15 % of fiber content, the flexural strength of oil palm and coir fiber-reinforced composites exhibit the same flexural behavior. The incorporation of fiber improves the absorption mechanism and micro crack resista . The flexural strength of the concrete increases with increasing the fiber length was observed. Higher content of fiber results reduction in flexural strength (Mohamed and Ismail, 2008). The flexural strength and modulus of elasticity are increased with an increase in NaOH concentration up to 8 % concentration and thereafter decreases. The flexural strength is increased from 3.6 MPa to 7.3 MPa after treatment. It is due to the better fiber–matrix bonding developed by the reduction in spiral angle and better molecular orientation of fiber after treatment.

Kroehong et al. (2018) studied the performance of OPEFB fiber in geopolymer composites investigated the various parameters of fly ash-based geopolymer mortar by addition of OPEFB fiber content The development of construction materials have posed problems and challenge that initiated worldwide research programs and continued conventional and non-conventional applications leading to ultimate economy. Researchers developed waste management strategies to apply for advantages for specific needs**.**

Bayapureddy Y et al. (2012) accomplished the use of Copper Slag (CS) and Ferrous Slag (FS) in concrete provides environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of CS and FS is produced. CS and FS are by-products obtained during matte smelting and refining of CS and FS. This work reports an experimental procedure to investigate the effect of using CS and FS as partial replacement of sand.

Adithya kumar Tiway et al. (2013) the strength characteristics of conventional concrete and slag concrete such as compressive strength, tensile strength were found. Six series of concrete mixtures were prepared with different proportions of CS and FS ranging from 0% to 100%. The test results of concrete were obtained by adding CS and FS to sand in various percentages ranging from 0%, 20%. 40%, 60%, 80% and 100%. All specimens were cured for 7, 28, 60 & 90 days before compression strength test and splitting tensile test. The results indicate that workability increases with increase in CS and FS percentage. The highest compressive strength obtained was 46MPa (for 100% replacement) and the corresponding strength for control mix was 30MPa.The integrated approach of working on safe disposal and utilization can lead to advantageous effects on the ecology and environmental also. It has been observed that upto 80% replacement, CS and FS can be effectively used as replacement for fine aggregate. Further research work is needed to explore the effect of CS+FS as fine aggregates on the durability properties of concrete.

2.1 RESEARCH SIGNIFICANCE

Aggregates are essential components of concrete and have a significant impact on the fresh and hardened properties of the material. These are depleting in some regions and countries, and the trend now is to use more crushed and manufactured aggregates, as well as recycled material. As a result, an obvious green solution is to use waste materials or byproducts as aggregate replacement materials. The use of recycled aggregate is especially promising because aggregates alone account for 75% of the volume of concrete. Copper slag can be utilized successfully as a fine aggregate. Concrete has been shown to have a high level of fire resistance and can be described as virtually fireproof in the majority of applications. The workability of copper slag which is a byproduct obtained from smelting procedure of copper is lower, but mixing it with special materials such as superplastisizers improves it. When using copper slag concrete, you can get a significant increase in its mechanical properties.

One of the most abundant agricultural wastes in Nigeria is the by-product of oil palm processing factories, which is oil palm empty fruit bunch (OPEFB) fiber. The OPEFB consists of a bunch of fibers readily available at low cost. OPEFB fibers are extracted by a retting process from empty fruit bunch. The fibers can also be converted to useful products such as fuel, fertilizer, and mulching materials. However, OPEFB fiber presents considerable emission problems when used as fuel. A natural fiber–cement composite has been used extensively in construction materials and processes such as insulating, cladding, noise barriers, and house building. The use of agricultural residues is preferable to virgin natural fibers due to environmental concerns. Most agricultural wastes are low-cost, lightweight, biodegradable, and environmentally friendly, and are obtained from renewable sources.

Plant fibers are of biological and lingo-cellulosic origin which are composed of chemical constituents (lignin, tannins resins, salts, silica, waxes, and ash) and polysaccharides (soluble sugar, starches, cellulose, and hemicelluloses), some of which impair the reaction between the woody element and inorganic cement binder as well as affect cement curing and setting time. Also, the inherent susceptibility of cellulosic fibers to moisture expansion is one of the obstacles of a natural fibers reinforced composite

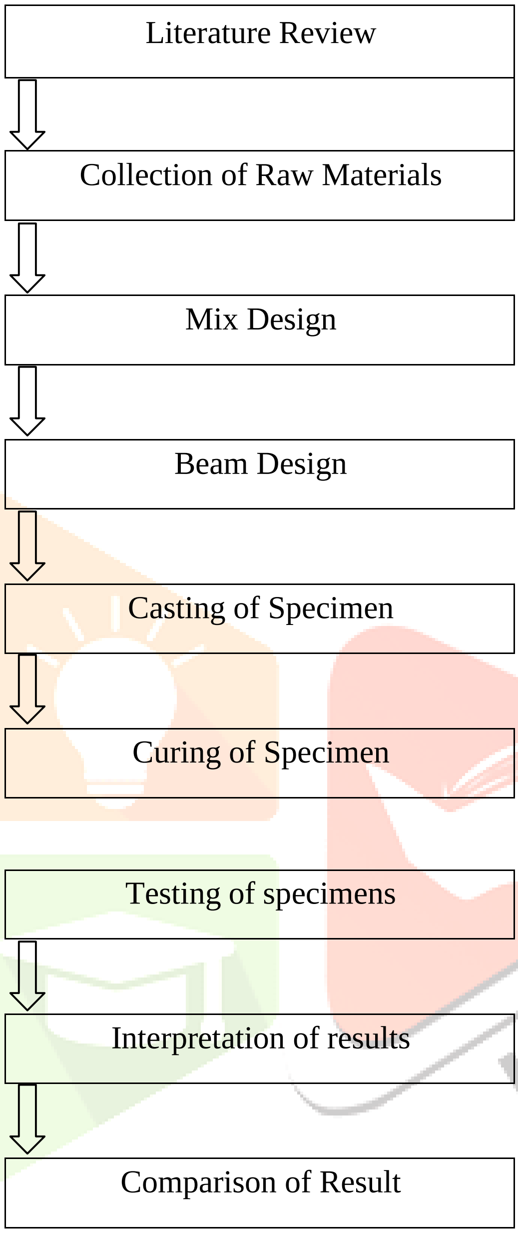
2.2 AIM

To investigate mechanical properties of EFBF reinforced self compacting concrete with partial replacement of fine aggregate by copper slag

2.3 OBJECTIVE

- To satisfies workability criteria for self-compacting concrete with fine aggregate partially replaced with copper slag and with EFBF reinforcement
- To study the strength characteristics of self-compacting concrete with partial replacement of fine aggregate with copper slag
- To investigate durability properties of empty fruit bunch fiber reinforced self-compacting concrete

CHAPTER 3 METHODOLOGY



CHAPTER 4 PRELIMINARY TESTS ON MATERIALS

4.1 GENERAL

The quality as well as the characteristics of the concrete depends on the properties of its ingredients. Hence preliminary test on cement, fine aggregate, coarse aggregate and copper slag were conducted as the initial steps of the project. The materials used for the preparation of self-compacting concrete of grade 30 were OPC (Ordinary Portland Cement) of 53 grade, fine aggregate, coarse aggregate, copper slag and super plasticizer. Each materials were tested as per the specification in the IS codes.

4.2 CEMENT

Ordinary Portland Cement (53 grade) – ULTRATECH confirming to IS 12269- 1987 was used for the experimental program. Tests were conducted as per IS: 1489(Part I). Details of the test are given in appendix A. The properties of the cement are tabulated in Table 4.1. The various tests conducted on cement are fineness of cement, standard consistency test, specific gravity, initial and final setting time and compression test on mortar cube.

Fig. 4.1 OPC of 53 grade

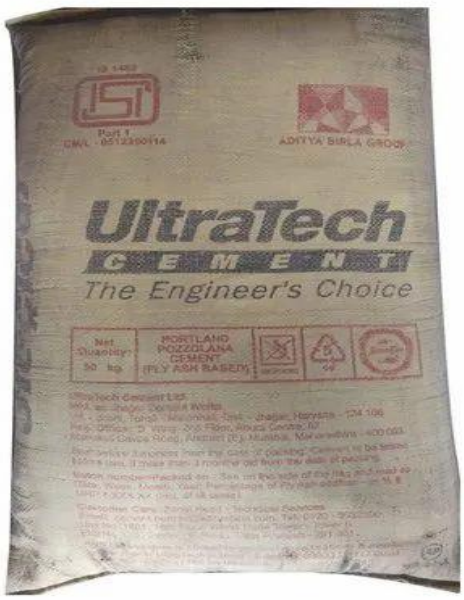


Table 4.1 Properties of Cement [13]

Sl. No.	Test Conducted	Result
1	Fineness (%)	4.80
2	Standard Consistency (%)	30.00
3	Specific Gravity	3.04
4	Initial setting time (minutes)	80
5	Mortar cube strength (N/mm^2)	30.14

4.3 FINE AGGREGATE

M – Sand was used as fine aggregate. Laboratory test were conducted on fine aggregateto determine the different physical properties as per IS2386 (Part–III)–1963 and IS: 383- 1970. The Details of the test is given in Appendix B. The properties of the fine aggregate are given in Table 4.2. The tests conducted on fine aggregate were grain sieve analysis, specific gravity and bulk density.

Table 4.2 Properties of Fine Aggregate [16]

Sl. No.	Test Conducted	Result
1	Fineness modulus	2.90
2	Zone of aggregates	II
3	Specific gravity	2.57
4	Bulk density(g/cc)	0.30

4.4 COARSE AGGREGATE

Coarse aggregate is defined as aggregate that passes through a 20 mm IS sieve but is retained on a 4.75 mm IS sieve. Here the coarse aggregate is retained in 12.5mm sieve. Various coarse aggregate tests were carried out in accordance with IS:2386

(Part 1 & Part 3). Details of the tests are given in Appendix C. The properties of coarse aggregate determined as given in Table 4.3. Tests conducted on coarse aggregate were grain sieve analysis, specific gravity and bulk density.

Table 4.3 Properties of Coarse Aggregate [18]

Sl. No.	Tests	Result
1	Specific gravity	2.699

4.5 WATER

Water is required to wet the surface of aggregate to develop adhesive quality as the cement paste binds quickly and satisfactorily to the wet surface of the aggregates than drysurface. It is widely accepted that any portable water can be used in the production of concrete. It should have inorganic solid less than 1000 ppm and should be free from injurious quantities of alkalis, acids, oils, salts, sugars, organic materials, vegetable growth or other substance that may be deleterious to bricks, stones, concrete or steel.

4.6 ADMIXTURE

Admixtures are defined in ACI116R as "a material other than water, aggregates, hydraulic cement, and fiber reinforcement, used as an ingredient of concrete or mortar, and added to the batch immediately before or during its mixing". Chemical admixtures are added to concrete to improve its quality during mixing, transportation, placement, andcuring.

MASTER RHEOBUILD1126ND is an admixture of a new generation based on modified poly carboxylic ether. The product was designed primarily for use in high-performance concrete applications requiring the highest durability and performance. MASTER RHEOBUILD 1126ND is free of chloride & low alkali. It works with all types ofcements.

MASTER RHEOBUILD 1126ND has a different chemical structure from the traditional superplasticizers. A carboxylic-ether polymer with long side chains is used to make it. It initiates the same electrostatic dispersion mechanism as traditional super plasticizers at the start of the mixing process, but the side chains linked to the polymer backbone generate steric hindrance, which greatly stabilizes the cement particles' ability to separate and disperse. Steric hindrance provides a physical barrier (alongside the electrostatic barrier) between the cement grains. With this process, flowable concrete with greatly reduced water content is obtained.

Table 4.4 Performance Data [7]

Aspect	Light brown liquid
Relative density	1.08 ± 0.01 at 25°c
pH	≥ 6
Chloride Ion content	<0.2%

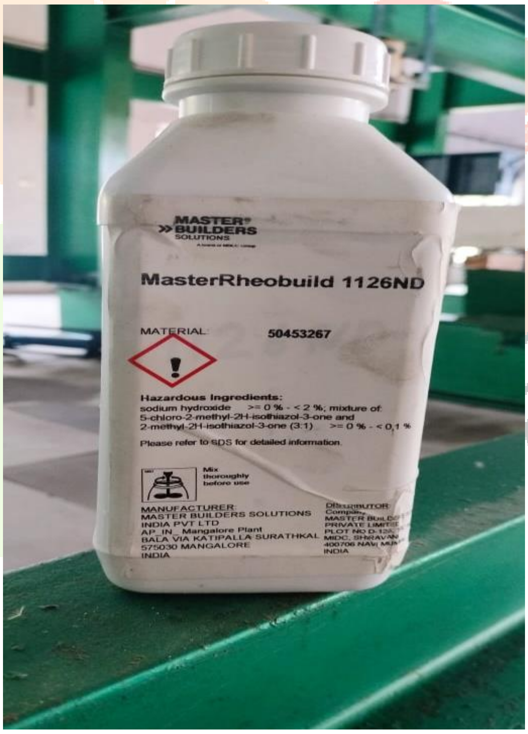


Fig. 4.2 Chemical Admixture

4.7 COPPER SLAG

Copper slag is a waste product obtained during the smelting procedure of copper. During smelting the impurities that formed as a result become slag and float on the molten metal.

Fig. 4.3 Copper Slag

Table 4.5 Physical Properties of Copper slag [19]

Sl. No.	Physical Property	Test Result
1	Fineness modulus	2.90
2	Specific gravity	2.8
3	Zone	2
4	Colour	Black
5	Texture	Glassy
6	Shape	Angular
7	pH	7

s

Table 4.6 Chemical Composition of Copper slag [19]

Sl. No.	Chemical Composition	Percentage Content
1	Silica (SiO_2)	30
2	Iron Oxide (Fe_2O_3)	29
3	Alumina (Al_2O_3)	10
4	Calcium Oxide(CaO)	4.9
5	Magnesium Oxide (MgO)	3.5
6	Total sulphur(SO_3)	0.98

CHAPTER 5 MIX DESIGN

5.1 GENERAL

The flow ability and viscosity of cement paste can be controlled by proper proportioning of water/powder ration and then adding super plasticizer and VMA.

The workability of SCC is higher than the highest class of consistence and can becharacterized by the following properties:

- Filling ability
- Passing ability
- Segregation resistance

A concrete mix can only be classified as Self-compacting Concrete if the requirements forall three characteristics are fulfilled. There is no special codes for mix design of SCC, andhence by going through several journals we adopted the IS code method for mix design and then the mix was adjusted according to the guidelines and specifications provided by EFNARC, So that the above properties of SCC are satisfied.

5.2 INITIAL MIX COMPOSITION

In designing the mix it is useful to consider the relative proportions of the key component by volume rather than by mass. Indicative typical ranges of the proportions and qualities in order to obtain self-compatability are given below. Further modifications will benecessary to meet strength and other performance requirements.

- A water/powder volume ratio of 0.80 to 1.10
- Total powder content -160 to 240 litres (400-600kg) per cubic meter
- Coarse aggregate content normally 28 to 35 percent by volume of the mix

- Water: cement ratio is selected based on requirements in IS10262:2009. Typicallywater content does not exceed 200 litre/m^3.
- The sand content balances the volume of the other constituents

Generally, it is advisable to design conservatively to ensure that the concrete is capable ofmaintaining its specified fresh properties despite anticipated variations in raw material quality. Variation in aggregate moisture content should also be expected and accommodated during the mix design process. Normally, viscosity-modifying admixtures are a useful tool for compensating for fluctuations caused by variations in sand grading and aggregate moisture content.

5.3 MIXING

There is no requirement for any specific mixer type. Forced action mixers, including paddle mixers, free fall mixers, including truck mixers, and other types can all be used. Generally, mixing times need to be longer than for conventional mixes.

5.4 DESIGN OF SCC

The mix proportion for SCC-30 grade of concrete was arrived, and design was done based on IS 10262:2009. Detailed mix design details are given in Appendix D. The mix proportions for SCC-30 grade of concrete are shown in Table 4.1.

The sequence of mix design is as below

- Designation of desired air content (mostly2%)
- Determination of coarse aggregate volume
- Determination of sand content
- Design of paste composition
- Determination of optimum water– powder ratio and superplasticizer dosage inmortar
- Finally the concrete properties are assigned by standard test

5.5 WORKABILITY OF FRESH SCC

A concrete is said to be workable if it can be easily placed and homogeneously compacted without any bleeding or segregation. It affects the strength, durability as well as the cost of labour and appearance of the finished product.

The workability of SCC is higher than the highest class of consistence and can be characterized by the following properties.

1. Filling ability
2. Passing ability
3. Segregation resistance

The above properties of SCC are satisfied as per IS code method for mix design and then fresh and hardened properties were fulfilled according to the guidelines and specifications provided by EFNARC, So that the above properties of SCC were satisfied. For the initial mix design of SCC all workability parameters need to be assessed to ensure that all aspects are fulfilled.

Table 5.1 Test Results on Fresh Concrete

Sl. No.	**Trial Mix**	**V-funnel (Sec)**	**T50cm (Sec)**	**L-box (H2/H1)**
1	SSC1	12	40	0.2
2	SSC2	8	37	0.4
3	SSC3	12	23	0.6

5.6 CASTING OF SPECIMENS

For casting the specimens, required quantities of the constituents were weighed and kept ready for mixing. For easy removal of the specimens, oil was applied to the inner surfacesof the moulds. The amount of super plasticizer to be used was calculated and set aside for later use. Before mixing the super plasticizer was mixed with the quantity of water. At first, all the ingredients are mixed well in dry condition and after that calculated amountof water with super plasticizer were added to the dry mix.

Fig. 5.1 Casting of SCC Specimens

5.7 CURING OF SPECIMEN

After 24 hours from casting, the specimens were removed from the mould and were water cured for 28 days by keeping in a water tank. The RC beams were cured using wet gunny bags and water was applied three times in a day. After 28 days, specimens were taken out and kept ready for testing. Fig 4.2 shows the image of specimens immersed in curing tank.

.

Fig 5.2 Curing of Specimens

5.8 TEST ON HARDENED SCC

The hardened concrete after cuing must be strong enough to withstand the structural and service loads applied on it and must be durable enough to withstand the environmental exposure for which it has been designed. If the concrete is properly proportioned, mixed, handled, placed and finished with high-quality materials, it will be the strongest and one of the most durable building materials.

The properties of hardened concrete, such as compressive strength, split tensile strength and flexural strength of concrete mixes were determined by casting cube specimens of size 150 mm x 150 mm x 150 mm, cylinder specimens of 150 mm x 300 mm S

5.9 FLEXURTAL TESTS ON SCC

SCC beams were tested for pure bending. Comparison between SCC beams of normal SCCand CS+ 1% EFBF mix concrete were studied. The results were then compared with the controlspecimens. The beams were designed to be weak in flexure.

5.1 SPECIMEN DETAILS

Beams of size 150 mm x 200 mm x 1250 mm were used for the experiment. A total of 4 specimens were casted.

Fig. 5.1 Mould for Beam Specimen

5.2 REINFORCEMENT DETAILS

The beams were designed as under reinforced sections according to IS: 456-2000. The design of beam is described in appendix E. The reinforcement details are given in Table 5.1. The reinforcement cage is shown in Figure 5.2.

Table 5.1 Reinforcement Details

Main Reinforcement	Anchor Bars	Stirrups
2 # 8mm dia	2 # 8mm dia	8mm dia @ 125mm spacing

Fig. 5.2 Reinforcement Cage

5.3 PREPARATION OF SPECIMEN

The required quantities of cement, fine aggregate, coarse aggregate and water was taken for the specimens. Initially cement, fine aggregate and coarse aggregate was hand mixed in dry state for about 2 minutes. The measured quantity of water was added stage by stage.Super plasticizer was used to increase the workability.

5.3.1 Casting of Specimens

The mould was prepared by applying oil on all contact surfaces. Reinforcement cage wasplaced in the beam mould with suitable cover blocks. The mould was filled with the prepared concrete mix with uniform compaction. Casting of specimens was done in two layers and each layer properly compacted using a tamping rod. Proper surface finishing was also done. The specimen after casting is shown in Figure 5.3. After 24 hours of casting, the specimens were demoulded and kept for curing.

Fig. 5.3 Specimens after Casting

5.3.2 Curing of Specimens

The casted specimens were demoulded after 24 hours and were subjected to water curingfora period of 28 days.

Fig. 5.4 Curing of Beams

5.4 TEST RIG AND INSTRUMENTATION

Beams were subjected to flexural strength test. The test setup consists of a 30 tonne loading frame. The deflection of the beam was determined by attaching a dial gauge at thebottom center of the beam. For testing of the beam specimens, the supports were providedat a distance of 130 mm from the edge of the beam. In case of a beam of span 1250 mm, the effective span is taken as 990 mm. A proving ring of 500 kN is attached at the top of the beam to determine the applied load. The schematic diagram of test setup is shown in Figure 5.5. The test setup for loading specimens is shown in Figure 5.6.

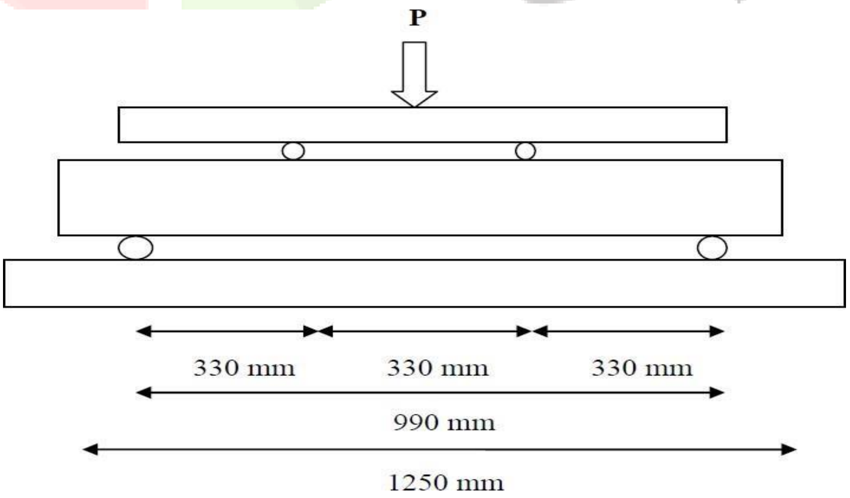


Fig. 5.5 Schematic Diagram of Experimental Setup

Fig. 5.6 Test Setup for Loading Specimens

The flexural strength of beam is tested with a two point loading system with the help of ahydraulic jack attached to the loading frame. The behavior of beam from beginning to thefailure was observed carefully. The loading of the beam was terminated just on the vergeof collapse. The development and propagation of first crack was observed keenly. The values of applied loads and the corresponding deflections were noted and the load- deflection curve is plotted which is taken as the output. The load is applied uniformly perpendicular to the beam and is incremented up to the breaking point or failure of the material.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 GENERAL

This chapter deals with results of various tests conducted. The results are divided into properties of hardened concrete load deflection on beam ultimate load and crack load results

6.2 PROPERTIES OF HARDENED CONCRETE

The average 28 day compressive strength and split tensile strength for different concretemix with variation in percentage of fiber and CS is shown in Table 6.2

Table 6.1 Test Results on Hardened SCC with CS

Mix	Average Compressive Strength (N/mm2)	Average Split Tensile Strength (N/mm2)
20% CS	31.48	3.10
30% CS	36.96	3.22
40 % CS	27.33	2.06

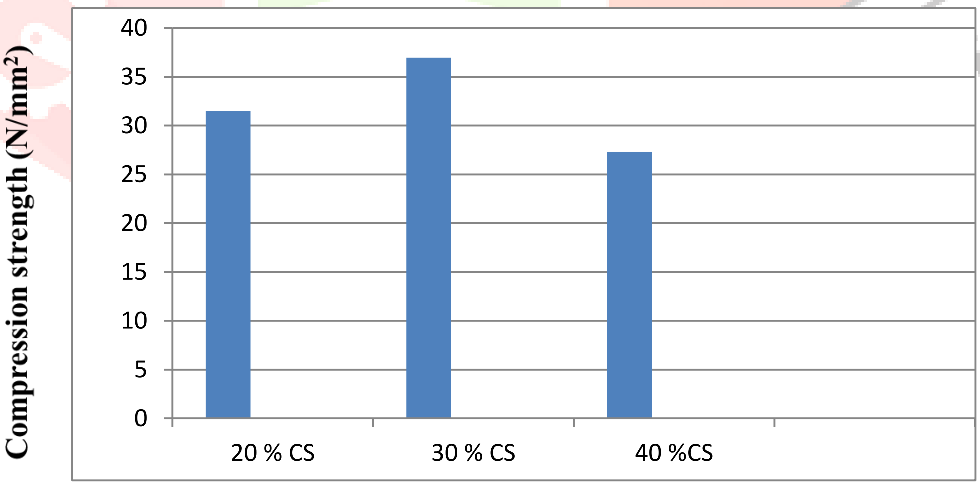


Fig. 6.1 Graph of average compression strength with various percentage of CS

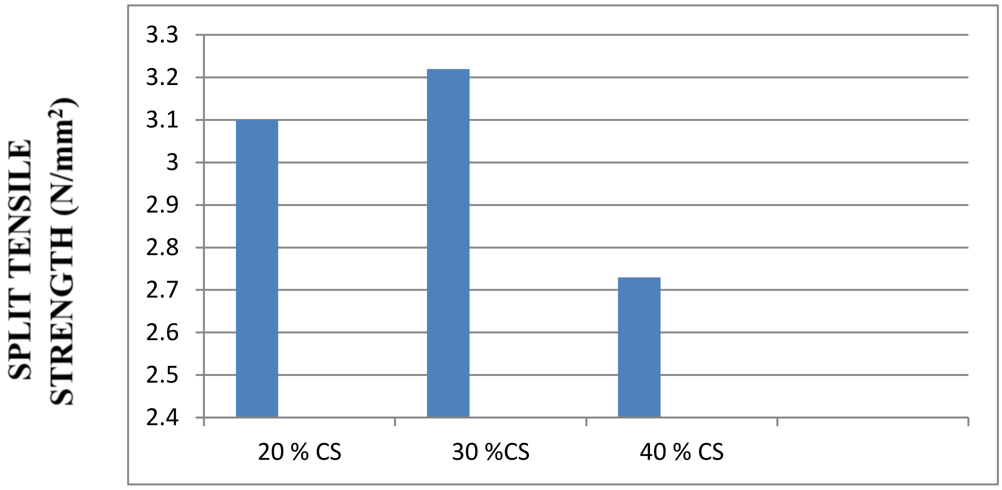


Fig. 6.2 Graph of average split tensile strength with various percentage of CS

Table 6.2 Test Results on Hardened SCC with CS and EFBF

Mix	Average Compressive Strength (N/mm2) After 7th day	Average Compressive Strength (N/mm2) After 28th day
Control Specimen	21.26	36.20
30% CS + 0.5% Fiber	27.40	37.20
30% CS + 1% Fiber	36.00	43.30
30% CS + 1.5% Fiber	24.13	33.16

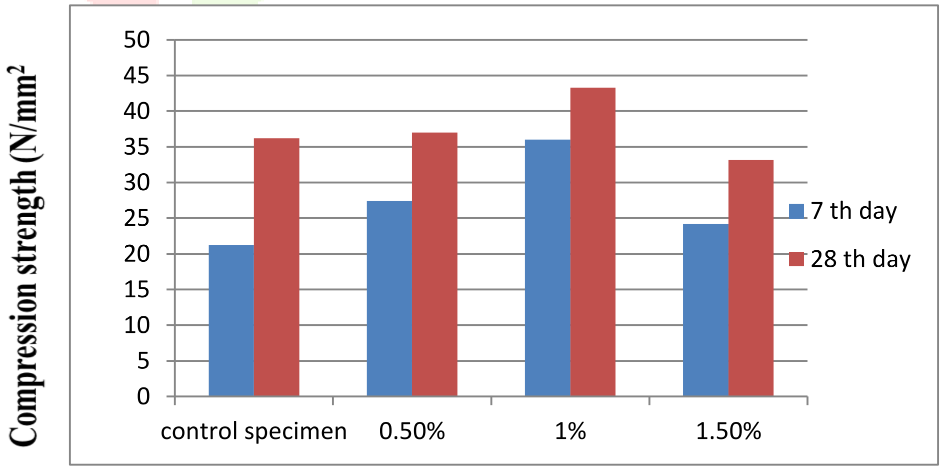


Fig. 6.3 Graph of Average Compression Strength with Various Percentage of Fiber

Table 6.3 Test Results on Hardened SCC with CS and EFBF

Mix	Average Spilt Tensile Strength (N/mm2)
Control Specimen	2.5
30% CS + 0.5% Fiber	2.84
30% CS + 1% Fiber	4.37
30% CS + 1.5% Fiber	3.01

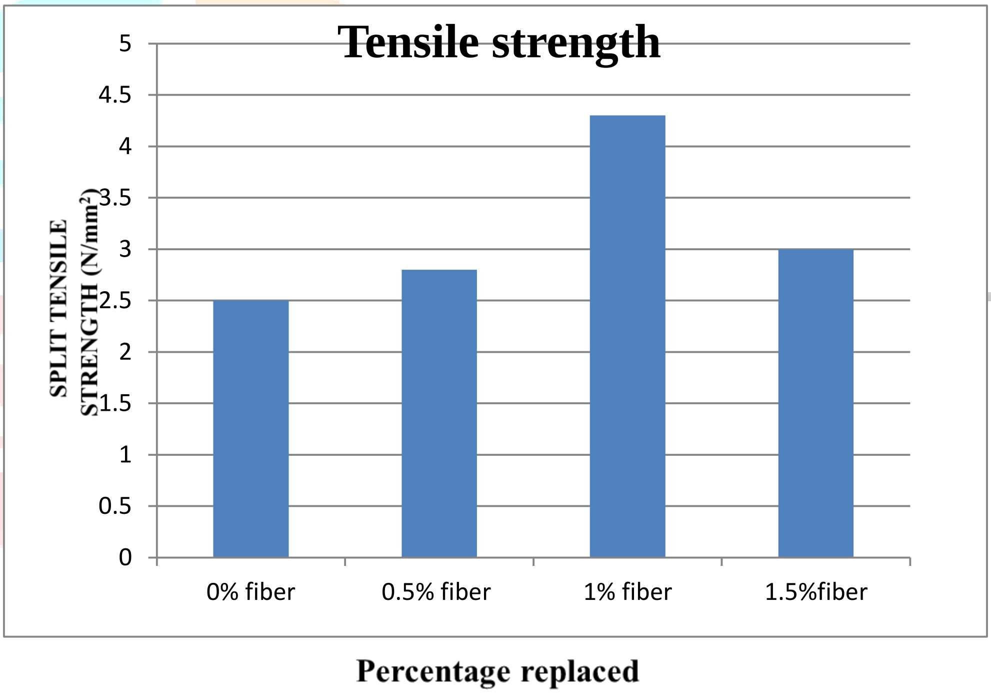


Fig. 6.4 Graph of average tensile strength with various percentage of CS

6.3 LOAD-DEFLECTION BEHAVIOR OF BEAM

Due to increase in the load, deflection of the beams starts, up to certain level the load v/s. Deflection graph will be linear that is load will be directly proportional to deflection. Due to further increase in the load, the load value will not be proportional to deflection, since thedeflection values increases as the strength of the materials goes on increasing material loseselasticity and undergoes plastic deformation. The deflection and the corresponding load, of SCC beam with CS+1% EFBF mix compared with conventional SCC beams. The values of loads andcorresponding deflections for control beam and externally strengthened beams are given inTable 6.1.

Table 6.1 Load- Deflection Values of Tested Specimens

eflection(mm)	**Load (kN)**	
	CS	**CS+1% EFBF**
0	0	0
0.5	14.20	23.00
1.0	39.20	44.00
1.5	89.00	90.20
2.0	108.30	108.37
2.5	136.00	139.00
3.0	160.20	167.7
3.5	169.78	170.6
4.0	170.64	176.6
4.5	156.88	170.00
5.0	152.64	163.00
5.5	147.00	161.00
6	147.00	159.00

Load-Deflection Curves

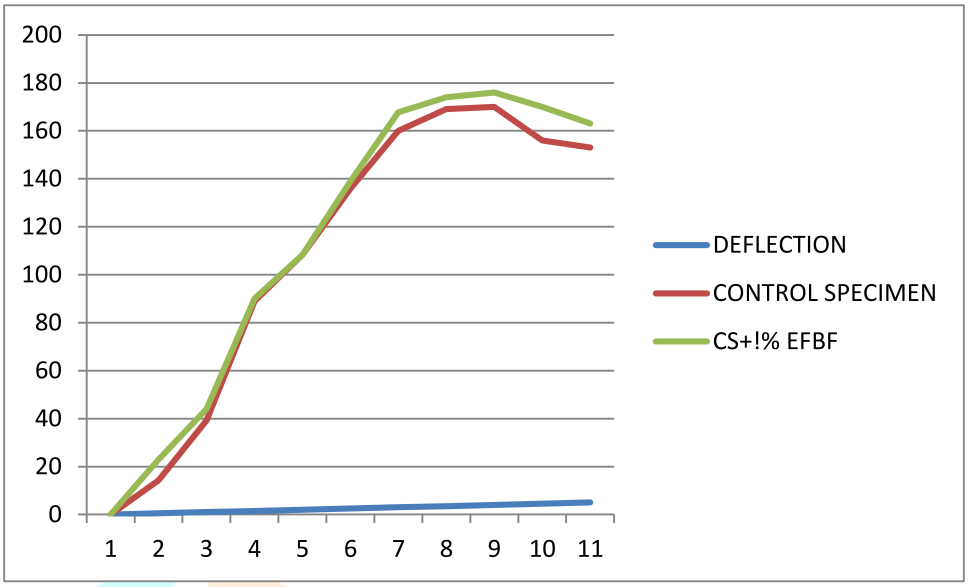
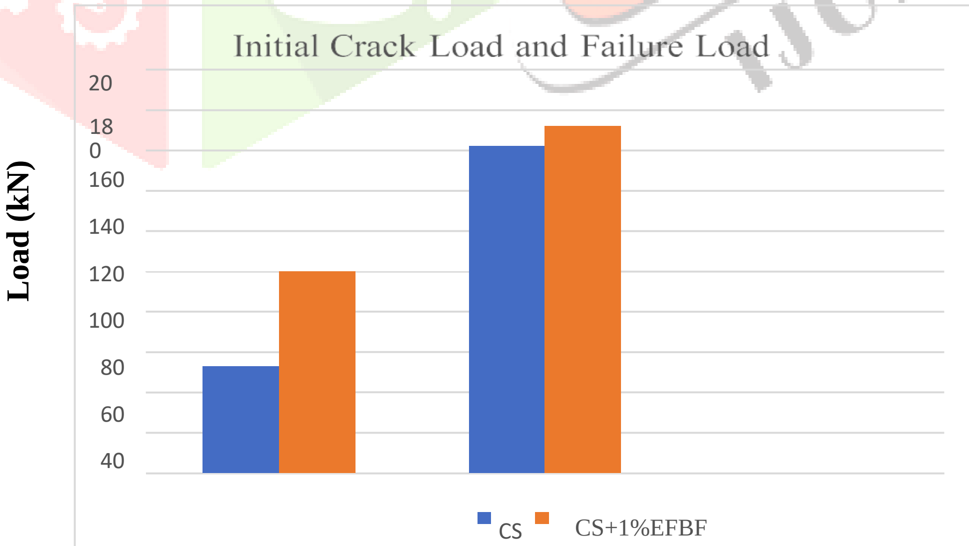


Fig. 6.1 Load-Deflection Curves for Specimens

6.1 LOAD CARYING CAPACITY

The initial crack loads for CS+1%EFBF mix beams are higher than that for control beams, i.e., for the second beams the initial crack has occurred at higher loads. The graph comparing theinitial crack load and failure load is shown in Figure 6.2. The values of ultimate load carryingcapacity of the specimens are listed in Table 6.2.



6.2 Initial Crack Load and Failure Load of Specimen

Table 6.2 Ultimate Load Capacity of Specimens

Beam Specimen	Ultimate Load (kN)
Control Mix	162.646
CS+EFBF	170.53

The ultimate load carrying capacities of CS+1%EFBF beam are higher than that of control specimen. The ultimate load carrying capacity increased by 4% for beams with CS+1%EFBF when compared with the control specimens. The graph showing ultimate load for CS+1%EFBF beam with respect to the control specimen is shown in Figure 6.3.

Fig. 6.3 Ultimate Load of Tested Specimens

6.2 CRACK PATTERNS

In the under reinforced beam section the member approaches failure due to gradual reduction of compression zone exhibiting cracks which develops at the soffit of the beam and progresstowards the compression face. During the test, cracks were initiated from the tensile face ofthe beam and propagated upwards towards the compression zone of the beam. As the load increased, more cracks were initiated and propagated. The number of cracks occurred in thecontrol beam is more than that in CS+1% EFBF beam (by visual).

CS+1%EFBF beam specimens showed an increase in initial crack load when compared to control specimen. In all the cases, the crack concentration was located in the pure bending region. There were no shear cracks in any beams. Cracking loads for first, second cracks inall the tested specimens are tabulated in Table 7.3. The crack width is much less compared to CS+1%EFBF beam. The graph showing cracking loads of beam specimens are shown in Figure 6.4.

In test specimens, formation of cracks has been reduced i.e., the number of cracks has beenlesser than CS specimens. Thus it can be concluded that CS+1%EFBF SCC beams develop lessnumber of cracks. It was also observed that the spacing between cracks was also more. Thegraph showing the cracking loads of beams are shown in Figure 6.6. Crack patterns in beamspecimens are shown in Figure 6.7.

Table 7.3 Crack Loads of Tested Specimens

Specimen	**Crack Load(kN)**	
	1st Crack	**2nd Crack**
Control mix	53.03	134.74
CS+EFBF	100.53	160.73

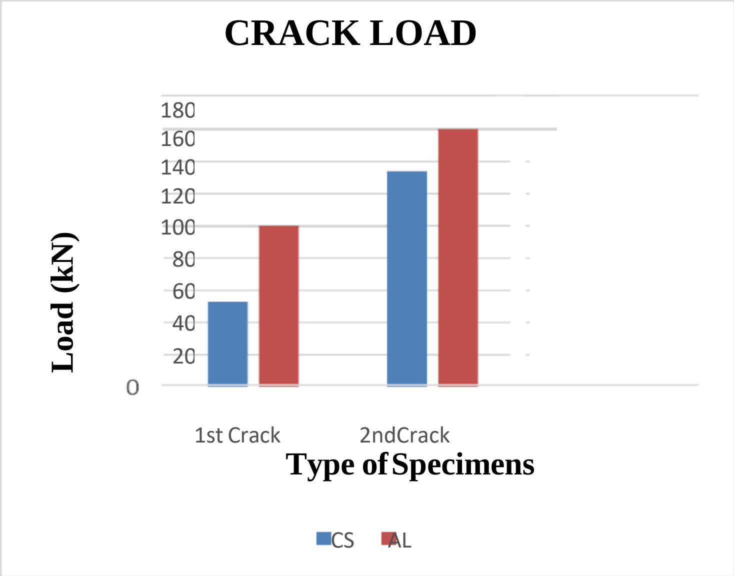


Fig. 6.6 Cracking Load

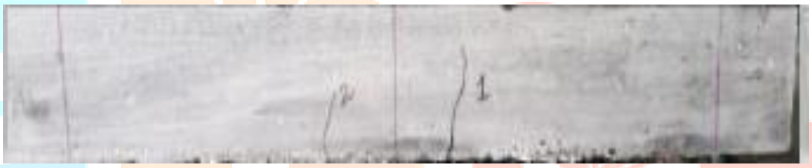


Fig. 6.7 Crack Pattern

6.3 FAILURE MODES

All the specimens were designed for flexural failure. The CS+EFBF specimen failed throughpure flexural failure by the development of flexural cracks. Rupture of CS+EFBF beam laminates at bottom of beam or crushing of concrete at top of beam was not observed till failure.

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 SUMMARY

An experimental program was conducted to evaluate the effect of incorporation of natural fiber reinforcement on self compacting concrete containing copper slag as partial replacement for fine aggregate on fresh and hardened properties.

8.2CONCLUSIONS

The main conclusions derived from this study may be summarized as follows:

1. As the percentage of CS increases, workability decreases. This can be improved by increasing water/cement ratio or by the use of some kind of water reducing admixtures.
2. Concrete mix with 1% fiber addition (30% Fine aggregate replacement with CS) shows better compressive and tensile strength
3. The optimum value of compressive and split tensile strength of CS + EFBF specimen are 43.30 and 4.37
4. Strength of SCC concrete decreases due to many reasons such as improper bonding of aggregate with cement paste and higher water absorption of CS.
5. The increase in the percentage of fiber leads to reduction compressive strength.
6. SCC beams with 30% CS had more load carrying capacity than CM (control mix)
7. All the specimens showed a linear relationship between load and deflection untilthe formation of cracks
8. RC beams with 30% CS with 1% EFBF had higher load carrying capacity and initial crack loadthan CM. The crack development in 30% CS with 1% EFBF specimen is much less compared toCS
9. The load deflection curve of CM and 30% CS with 1% EFBF specimen was almost same but the loadis greater in second specimen. The number of crack and crack width is much less than that of CM specimen

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[12] IS10262:2009 [mix design]

[13] IS 4031-1988 [Standard consistency of cement]

[14] IS 2720(Part III) [Specific gravity of cement]

[15] IS 12269-1987 [Fineness of cement]

[16] IS2386(Part-III)-1963 [Fine aggregates]

[17] IS383:1970 [sieve analysis]

[18] IS2386(Part-III)-1970 [coarse aggregate]

[19] EFNARC-Specifications and Guidelines for Self Compacting Concrete

APPENDIX A

TEST ON CEMENT

A. 1 FINENESS OF CEMENT

Table A. 1 Test Results on Fineness of Cement

Sl. No.	l Weight(gm)	eight Retained onthe Sieve (gm)	Average Weight of Residue
1	100	5	
2	100	7	6.33
3	100	7	

Fineness of cement = 6.33 %

Inference: As per IS 4031 – 1948, weight of residue should be less than 10 %, the obtainedvalue is 6.33 %. Hence, this cement is suitable for concreting purpose.

A.2 STANDARD CONSISTENCY OF CEMENT

Table A. 2 Test Results on Standard Consistency of Cement

Sl. No.	Weightof Dry Cement(gm)	Percentageof WaterAdded	Weight of Water Adde d (ml)	Penetration from Bottom ofMould (mm)
1	300	28	84	34
2	300	30	90	29
3	300	32	96	8
4	300	34	102	1

The standard consistency = 34 %

Inference: As per IS 4031-1988 part IV, the percentage of water for standard consistency for cement varies between 25 – 35 % of water by weight of cement. The obtained value is34%, this cement is good for RCC work.

Fig. A. 1 Standard Consistency Testing

A. 3 SPECIFIC GRAVITY OF CEMENT:

Weight of empty flask (W1)	= 23.4 g
Weight of flask + cement (W2)	=73.4g
Weight of flask+ cement+ kerosene (W3)	= 115 g
Weight of flask + kerosene (W4)	= 78.7g
Specific gravity of kerosene	= 0.79

Specific gravity of cement $= \frac{(w2-w1)}{(w2-w1)-((w3-w4)\times 0.79)}$

= 3.06

Inference: As per IS 4031-1988 part II, the specific gravity of cement ranges from 3.0 to 3.16. The obtained value is 3.06 and hence this cement is suitable for constructionalpurposes.

A. 4 INITIAL SETTING TIME

Table A. 3 Test Results on Initial Setting Time of Cement

Sl. No.	'ime Taken (Minutes)	ıetration(mm)	Remarks
1	0	0	-
2	10	4	-
3	20	4	-
4	30	4	-
5	40	4	-
6	50	4	-
7	70	4.5	-
8	80	5	Initial setting time

Weight of cement taken = 300 gm

Water added = 85 % of standard consistency × weight of cement = 86.7 ml

Fig. A. 2 Initial Setting Time Testing

Inference: As per IS 12269 – 2013, the minimum initial setting time for is 30 minutes and.The obtained value is within the limits and hence cement is of good quality

APPENDIX B

TEST ON FINE AGGREGATE

B. 1 SIEVE ANALYSIS ON FINE AGGREGATE

Weight of fine aggregate = 2 kg

Table B. 1 Test Results on Grain Size Distribution of Fine Aggregate

ve Size(mm)	Weight Retained in Each Sieve (gm)	Percentage Weight Retained	Cumulative % Weight Retained	ercentage Weight Passing	IS Range for Zone II
4.750	0.010	0.50	0.50	99.50	90 – 100
2.360	0.302	15.10	15.60	84.40	75 – 100
1.180	0.430	21.50	37.10	62.90	55 – 90
0.600	0.301	15.05	52.15	47.85	35 – 59
0.300	0.713	35.65	87.80	12.20	8 – 30
0.150	0.131	6.55	94.35	5.65	0-10

Fineness modulus $= \frac{\text{Sum of cumulative percentage weight retained}}{100}$

= 299/100

= 2.9

Fig. B. 1 Apparatus for Sieve Analysis

B.2 SPECIFIC GRAVITY OF FINEAGGREGATE

Table B. 2 Test Results on Specific Gravity of Fine Aggregate

Sl. No.	Weight of Pycnometer (W1)	Weight of Pycnometer +M. sand (W2)	Weight of Pycnometer + M. sand + Water (W3)	Weight of Pycnometer + Water(W4)	Specific Gravity(W)
1	0.690	1.189	1.955	1.650	2.574

Specific Gravity = $\frac{W2-W1}{((W2-W1)-(W3-W4))} = \frac{1.189-0.690}{((1.189-0.690)-(1.955-1.650))} = 2.574$

Inference: As per IS 2386-1963, the fineness modulus of fine aggregate (coarse sand) liesin the range of 2.9 – 3.2 and the specific gravity lies in the range 2.5 – 2.9. Here the obtained values are within the limits, hence it is suitable for construction purposes.

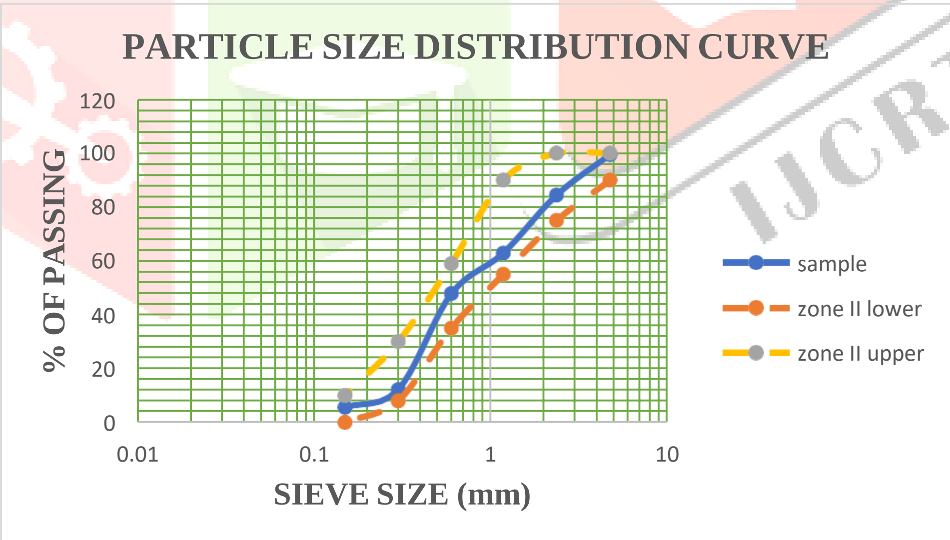


Fig. B. 2 Grain Size Distribution Curve of Fine Aggregate

APPENDIX - B

TEST ON COPPER SLAG

B 1 SIEVE ANALYSIS ON COPPER SLAG

Weight of copper slag = 2 kg

Table B.1 Test Results on Grain Size Distribution of Copper Slag [16]

eve Size(mm)	Weight Retained in Each Sieve (gm)	Percentage Weight Retained	Cumulative % Weight Retained	ercentage Weight Passing	Range for Zone II
4.750	0.010	0.50	0.50	98.50	90–100
2.360	0.307	16.10	15.60	84.40	75–100
1.180	0.430	21.7 0	37.10	62.90	55–90
0.600	0.301	15.05	52.15	47.66	35–59
0.300	0.713	35.65	87.80	12.20	8–30
0.150	0.131	6.55	94.35	5.65	0-10

Fineness modulus = Sum of Cumulative Percentage Weight retained/100

= 298/100

= 2.98

Fig. B. 1 Sieve Analysis

B.2 SPECIFIC GRAVITY OF COPPER SLAG

Table B.2 Test Results on Specific Gravity of Fine Aggregate [16]

Sl. No.	Weight of Pycnometer (W1)	Weight of Pycnometer + M. Sand (W2)	Weight of Pycnometer + I. Sand+Water	Weight of Pycnometer + Water (W4)	Specific Gravity (W)
1	0.590	1.172	1.655	1.650	3.12

Specific gravity = $\frac{W2-W1}{((W2-W1)-(W3-W4))}$

= 2.79

Inference: As per IS 2386(1) –1963, the fineness modulus of fine aggregate (coarse and) lies in the range of 2.9–3.2 and the specific gravity lies in the range 2.5–2.9. Here the obtained values are within the limits, hence it is suitable for construction purposes.

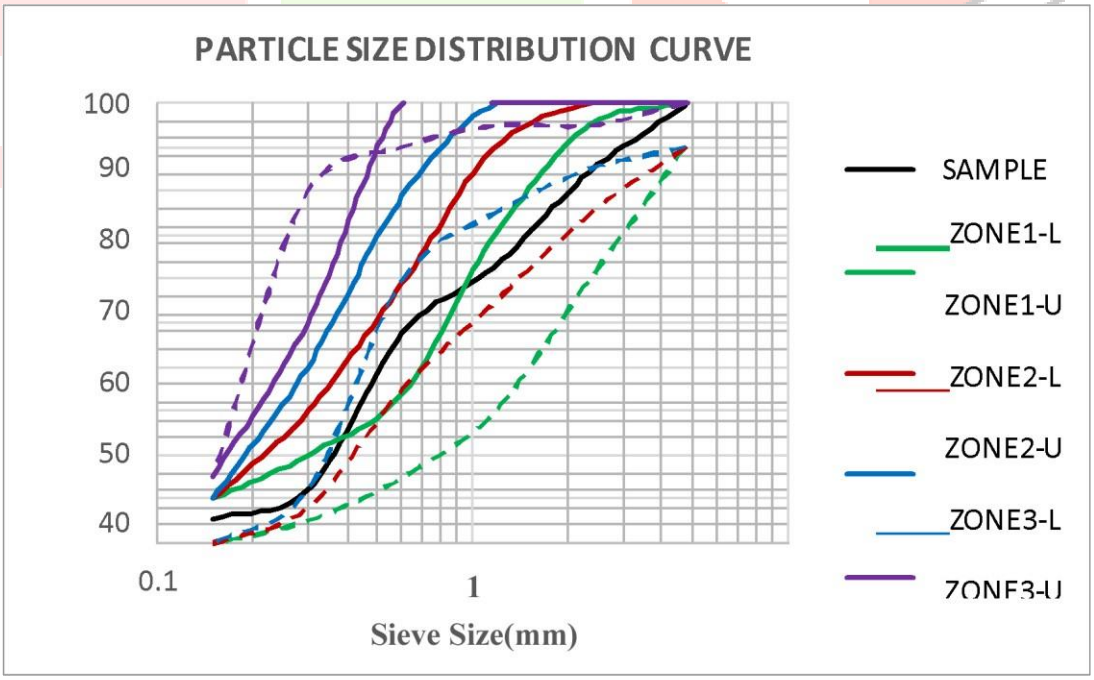


Fig. B.2 Grain Size Distribution Curve of Fine Aggregate [16]

APPENDIX C

TEST ON COARSE AGGREGATE

C.1 SPECIFIC GRAVITY OF COARSE AGGREGATE

Table C. 1 Test Results on Specific Gravity of Coarse Aggregate

Sl. No.	eight ofVessel (W_1) (Kg)	Weight of Vessel + Aggregate(W_2)	Weight of Vessel + Aggregate + Water (W_3)	Weight of Vessel + Water (W_4)	Specific Gravity
1	5.61	21.2	26.23	16	2.89

Specific Gravity $= \frac{W2-W1}{((W_2-W_1)-(W_3-W_4))}$

= 2.89

Inference: As per IS 2386-1963 part I, the specific gravity lies in the range 2.5 – 3. Here the obtained value is 2.89 which is within the limit, hence it is suitable forconstruction

APPENDIX D

MIX DESIGN

The mix proportion for the SCC 30 grade of concrete was arrived through trial mixes. Theconcrete designed based on IS 10262:2019. The mix is designed for pumpable concrete. The mix proportions for SCC 30 grade of concrete are as below: Grade designation: SCC 30

Type of cement : OPC 53 gradeExposure condition: : moderateMaximum w/c ratio : 0.45

Minimum content of cement : 320 kg/m3Workability of slump : 100 mm

Chemical admixture type : Superplasticizer, viscosity modifying agentStandard deviation : 5 (table 1, IS 10262: 2019)

Maximum size of aggregate : 12.5 mmSpecific gravity of cement : 3.125 Specific gravity of fine agg. : 2.572 Specific gravity of coarse agg. : 2.699

Step 1: Target strength for mix proportion

$f'_{ck} = f_{ck} + 1.65s$

Or

$f'_{ck} = f_{ck} + X$ Whichever is greater

$f'_{ck} = f_{ck} + X$ =30+6.5=36.5 N/mm^{2}From table 1 of IS 456: 2000

s = 5 N/mm^2

$f'ck = fck + 1.65s$ (From table 1 of IS 456: 2000 standard deviation = 5)

= 30 + 1.65 × 5 = 38.25 N/mm2

Step 2: Approximate Air Content

Entrapped air as percentage of volume of concrete = 1.4

Step 3: Selection of water – cement ratio

From table 5 of IS 456: 2000, Maximum water – cement ratio = 0.45

Here, the water cement ratio required for target strength of 38.25 N/mm^2 is 0.45

Step 3: Selection of water content

As per IS 10262: 2019

Maximum water content = 143 kg/m^3

Step 4: Calculation of cement content

Water – cement ratio = 0.45

Cement content = $water/0.45$ = 143/0.45 = 358 kg/m^{3}As per IS 456: 2000 Table 5

Minimum cement content = 320 kg/m^{3}Maximum cement content = 450kg/m^3 Therefore, cement content = 358 kg/m^3

Step 5: Aggregate proportion between Coarse aggregate and Fine aggregate

Nominal maximum size	Volume of Course Aggregate
10	0.50
12.5	0.53
20	0.62

Every 0.05 decrease, there is an increase of 0.01 of water cement ratio 0.45Therefore 0.53 + 0.01 = 0.54 For pumpable concrete coarse aggregate can be reduced upto 1% [IS10262- 2019, cl.5.5.2]Volume of coarse aggregate [10% of 0.54] = 0.45

Volume of fine aggregate=1- 0.5=0.5

Step 6: Mix calculation

Volume of concrete = 1m3

Volume of cement = Mas of cement/Specific gravity of cement = 1 /1000 =

= (358 /3.125)*(1/1000)= 0.128 m^3

Volume of water = 143/1000 = 0.143 m^3

Volume of Chemical Admixture = Mass of super plasticizer/specific gravity of superplasticizer [Here, mass =2% of cement] = 0.006

Volume of flyash =0.038

Volume of all in aggregate = 1- 0.344 = 0.656 m^3

Mass of coarse aggregate = 0.656 x 0.5 x 2.699 x 1000 =1231kg/m^3

Mass of fine aggregate = 0.656 x 0.5 x 2.572 x 1000 = 794 kg/m^3Summary:

Cement added = 35 kg/m^3Fly Ash = 80 kg/m^3

Fine Aggregate = 794 kg/m^3 Coarse aggregate = 1231 kg/m^3Water cement ratio = 0.45

Table D. 1 Mix Proportion of SCC

Cement	Fine Aggregate	Coarse Aggregate	Water
358	794	1231	172

Mix proportion: 1: 2.21: 2.21

APENDIX E DESIGN OF BEAM

Span, l = 1250 mm

Breadth, b = 150 mmDepth, D =

200 mmf_{ck} = 30 N/mm^2

f_y = 415 N/mm^2

Clear cover = 25 mm

Assuming 2 # 8 mm dia bars as the main reinforcement,

Effective depth, d = D – cover - Ø/2

= 200- 25 – 4 = 171 mm

Step 1: Selection of section As per IS: 456-2000 (page 70),$X_{u,max}$ /d = 0.48, for Fe 415

From annex G-1.1. a (IS: 456-2000),X_u /d = 0.87 f_y x A_{st} /0.36 f_{ck} bd

= 0.87x415x201.06 /0.36x30x150x 171

= 0.32

Here, X_u/d < $X_{u,\,max}$/d. Hence the section is under reinforced

Step 2: Calculation of moment

From annex G-1.1.c (IS: 456-2000),

Moment of resistance, $M_{u,\,limit}$ = 0.36 x ($X_{u,max}$/d)[1-0.42 x $X_{u,max}$/d] bd^2 f_{ck}

= 0.36 x 0.48 [1-0.42 x 0.48] 150 x 1712 x 30

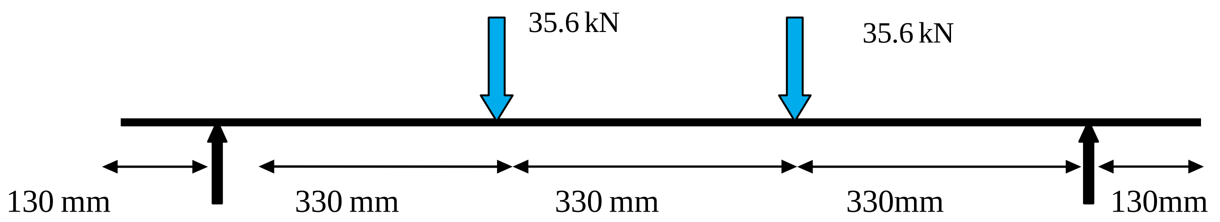
= 18.15 kNmFrom annex G-1.1.c (IS: 456-2000),

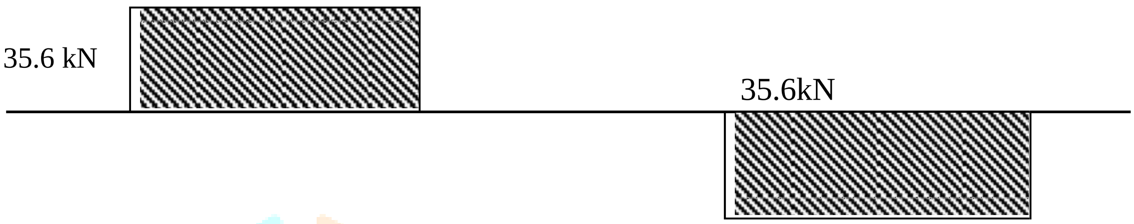
M_u = 0.87f_y A_{st} [1-A_{st} f_y/bd f_{ck}]

= 0.87×415×201.06×171 x [1 − 201.06 x 415] 150x171x30

= 11.067 kNm

Thus, Mu, limit > Mu. Hence ok.





SFD

BMD

Fig. E.1 Shear Force and Bending Moment Diagramw/2 × 330 = 11.75 × 106 Nmm

Therefore, w = 71.21 kN

Step 3: Calculation of shear reinforcement Assuming 2 legged 8 mm dia vertical stirrups, $A_{sv} = 2 \times (\pi/4) \times 8^2$

$= 100.53\ mm^2$

As per clause 40.1 (IS: 456-2000), Nominal shear stress, $r_v = V_u / bd$

= 35.606 x 1000 / 150 x 171

$= 1.366\ N/mm^2$

$100\ A_{sv} / bd$ = 100 x 100.53 / 150 x 171

= 0.39

Therefore, from table 19 (IS: 456-2000),Design shear strength, τ_c = 0.44 N/mm^2 From table 20 (IS: 456-2000),

Maximum shear stress, τ_c, max = 3.5 N/mm^{2}Thus, $\tau_c < \tau_v < \tau_{c,\,max}$.

Hence, as per clause 40.4 (IS: 456-2000), shear reinforcement shall be provided.Assuming shear reinforcement provided as vertical stirrups

Design shear, $V_{us} = V_u - \tau_c$ bd

= 35.606 x 103-0.44 x 150 x 171

= 24.32 kN

Step 4: Calculation of spacing of stirrups

As per clause 40.4 (IS: 456-2000),

Strength of shear reinforcement, $V_{us} = 0.87\ f_y\ A_{sv}\ d\ /\ s_v$

Therefore, spacing of stirrups, $S_v = 0.87\ f_y\ A_{sv}\ d\ /\ V_{us}$

= 0.87 x 415 x 100.53 x 171/ 24.32x 1000

= 255 mm

Step 5: Check for spacing of shear reinforcement

As per clause 26.5.1.5 (IS: 456-2000), the maximum spacing of shear reinforcement forvertical stirrups < 0.75d = 0.75 x 171 = 128.25 mm

< 300 mm

Hence provide spacing of 125 mm.

Step 6: Check for minimum shear reinforcement

As per clause 26.5.1.6 (IS: 456-2000),

A_{sv} / b S_v = 0.4 / 0.87 f_y

S_v = 0.87 x 415 x 100.53/ 0.4 x 150

= 604.93 mm

Hence, provide 2 legged 8 mm dia bars at a spacing of 125 mm centre to centre.

Step 7: Check for shear failure

Strength of shear reinforcement, $V_{us} = 0.87\ f_y\ A_{sy}\ d\ /s_v$

= 0.87 X 415 X 100.53 X 171/ 125

= 49.65 kN

$V_{us} = V_u - r_c$ bd

Therefore, shear force, V_u = 49.65 x 103 + (0.44 x 150 x 171)

= 60. 93 kN

V_u = w/2 = 60. 93 kN

Therefore, w = 121.86 kN > 71.21 kN Therefore, no shear failure. Hence safe.

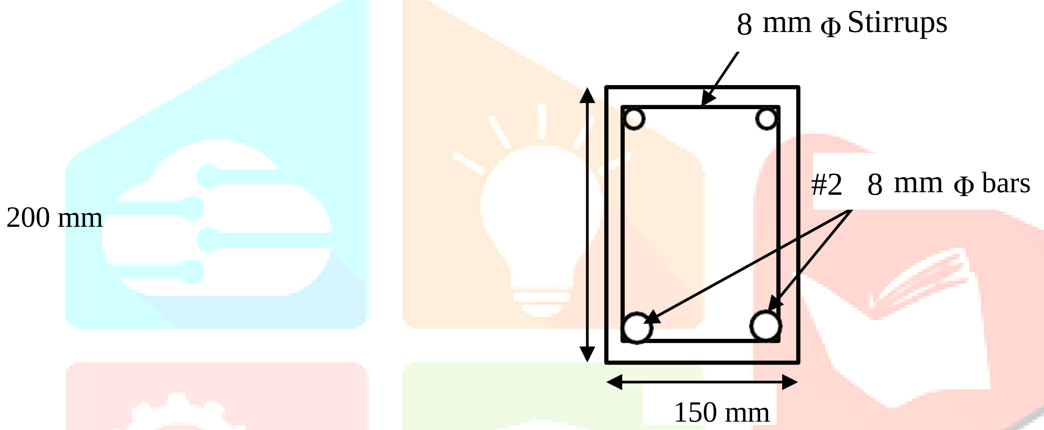


Fig. E.2 Cross Section of Beam

APPENDIX F
TEST METHODS ON SCC

Self-compacting concrete has the properties such as filling ability, passing ability and segregation resistance. Various workability methods are available for self-compacting concrete such as slump flow test by Abrams cone, T50 cm Slump flow Test, V- funnel test,L – box test, U – box test.

F. 1 TEST METHODS ON FRESH SCC

F. 1. 1 Slump Flow Test and T50 cm Test

The slump flow test is done to know the horizontal flow of concrete in the absence of obstructions. It gives good assessment of filling ability. During the slump flow test, the viscosity of SCC mixture can be estimated by measuring the time taken for the concrete toreach a spread diameter of 500 mm from the moment the slump cone is lifted. This is calledT50 measurement and typically varies between 3 – 7 seconds.

Procedure

1. Moisten the base plate and inside of slump cone
2. Place the base plate on level stable ground and the slump cone centrally on the baseplate and hold down firmly
3. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with thetop of the cone with the trowel.
4. Remove any surplus concrete from around the base of the cone.
5. Raise the cone vertically and allow the concrete to flow out freely.
6. Simultaneously, start the stopwatch and record the time taken for the concrete to reachthe 500mm spread circle. (This is the T50 time).
7. Measurethe final diameter of the concrete in two perpendicular directions.
8. Calculate the average of the two measured diameters. (This is the slump flow in mm).

Observations

Table F. 1 Test Results on Slump Flow Test of SCC

Sl. No.	Slump Flow Diameter (mm)	Range (mm)
1	590	500 -700

Table F. 2 Test Results on T_{50} cm Test of SCC

Sl. No.	T_{50} Value (Sec)	Range (Sec)
1	6.18	3 –7

Fig. F. 1 Slump Flow Testing

Inference: The higher the slump flow (SF) value, the greater its ability to fill form work under its own weight. A value of at least 650 mm is required for SCC.

There is no generally accepted advice on what are reasonable tolerances about a specified value, though ± 50mm, as with the related flow table test, might be appropriate.

The T50 time is a secondary indication of flow. A lower time indicates greater flowability.The Brite Eu Ram research suggested that a time of 3-7 seconds is acceptable for civil engineering applications, and 2-5 seconds for housing applications.

In case of severe segregation most coarse aggregate will remain in the center of the pool ofconcrete and mortar and cement paste at the concrete periphery. In case of minor segregation, a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will notoccur since this is a time related aspect that can occur after a longer period.

Hence the obtained value of slump flow and T50 cm lies within the range. And hence, the mix is said to flowable.

F. 1. 2 L – Box Test

This test, based on a Japanese design for underwater concrete, has been described by Peterson. The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus is shown in figure below.

Fig. F. 2 L - Box Testing

The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, then the gate liftedto let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1in the figure). It indicates the slope of the concretewhen at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted.

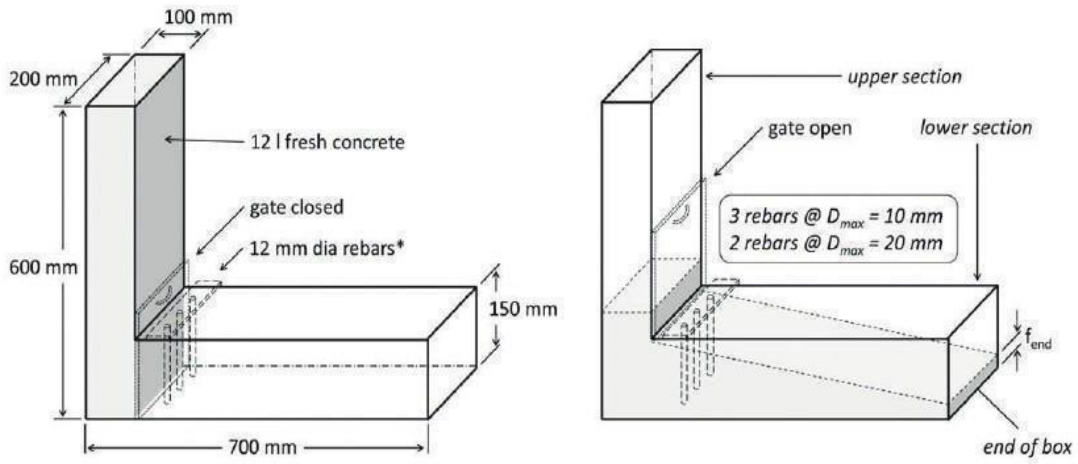


Fig. F. 3 Standard Dimensions of L – Box [28]

The sections of bar can be of different diameters and spaced at different intervals: in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete.

Procedure

About 14 litres of concrete is needed to perform the test, sampled normally.

1. Set the apparatus level on firm ground, ensure that the sliding gate can open freely andthen close it.
2. Moisten the inside surfaces of the apparatus, remove any surplus water
3. Fill the vertical section of the apparatus with the concrete sample.
4. Leave it to stand for 1 minute.
5. Lift the sliding gate and allow the concrete to flow out into the horizontal section.
6. When the concrete stops flowing, the distances H1 and H2 are measured. Calculate
1. H2/H1, the blocking ratio
7. The whole test has to be performed within 5 minutes.

Observations

Table F. 3 Test Results L-Box Test of SCC

Sl. No.	Blocking Ratio (H2 / H1)	Range
1	0.9	0.8 - 1

Inference: If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1=1.Therefore, the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. The observed value is unity and hence the mix is good enough with its passing ability.

F. 1. 3 V Funnel Test

This test was created in Japan. The apparatus consists of the V-shaped funnel depicted above. The V-funnel, as indicated in the diagram, is built of steel and has a flat, horizontaltop that is supported vertically, along with a releasable watertight opening gate. The V- Funnel test is used to measure the concrete's filling ability (flowability) with a maximum aggregate size of 20 mm. There are around 12 liters of concrete in the funnel. Calculate how long it took for it to flow down. After that, fill the funnel with concrete and set it asidefor 5 minutes to settle. If the concrete segregates, the flow time will dramatically rise.

Fig. F. 4 V-funnel Testing

Procedure

1. The entire test must be completed in under 5 minute.
2. Do not clean or damp the interior surface of the funnel for V-funnel flow.
3. After monitoring the flow time, quickly close the trap door and refill the V-funnel.
4. Place the bucket on the floor 5. Without tamping or tapping, thoroughly fill theapparatus with concrete.
5. Using a trowel, level the concrete at the top.
6. Allow the concrete to flow by opening the trap door 5 minutes after the second fill ofthe funnel.
7. Determine how long it takes for the entire discharge to be completed.

8. It's referred to as the flow time at T_5 min.
9. The flow time for the V-funnel test should be between 8 and 12 seconds.
10. T_5 min. + 3 seconds is allowed for V-funnel flow time.

V Funnel Test Calculation

V-funnel flow time (t_v) = 10 sec

F.2 TESTS ON HARDENED SCC SPECIMEN WITH PPF

F. 2. 1 Compressive Strength Test

The compressive strength of concrete represents one of the most important features used inthe design rules of the concrete structures, and many of other mechanical characteristics (e.g., tensile strength, modulus of elasticity, compressive strain) and physical properties (e.g. related to durability) of concrete are moreover expressed as a function of thisparameter.

Figure F.5 Compressive Strength Test of SCC M30 Mix with PPFObservations:

Table F. 4 Test Results on Compressive Strength of M30 SCC Cubes with

Mix	Average Compressive Strength (N/mm2)
0.5% PPF	24.25
15% CNSA+ 1% PPF	30.33
20% CNSA+ 1% PPF	9.24

Inference: The compressive strength of SCC was higher than VC with 15% for cube specimens.

F.2.2 Split Tensile Strength Test

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which theconcrete members may crack. Tensile strength of concrete is much lower than its compressive strength. It has been estimated that tensile strength of concrete equals roughlyabout 10 % of compressive strength

Observations:

Table F. 5 Test Results on Split Tensile Strength of M30 SCC with PPF

Mix	Average Split Tensile Strength (N/mm2)
0.5% PPF	2.30
15% CNSA+ 1% PPF	2.82
20% CNSA+ 1% PPF	2.06

Figure F.6 Split Tensile Strength Testing of SCC 30 Mix with PPF

Inference: The split tensile strength should be 2/3 rd of the modulus of rupture.Modulus of rupture = fcr = 0.7 $\sqrt{fck}$ = 0.7 √ 30 = 3.83 N/mm^2

Split tensile strength = 2/3 × fcr = 2/3 × 3.83 = 2.55 N/mm^2

F.3 TESTS ON HARDENED M$_{30}$ SCC MIX AND MIX WITH CNSA AND PPF

F. 3. 1 Compressive Strength Test

The compressive strength of concrete represents one of the most important features used inthe design rules of the concrete structures, and many of other mechanical characteristics (e.g., tensile strength, modulus of elasticity, compressive strain) and physical properties (e.g., related to durability) of concrete are moreover expressed as a function of this parameter.

Figure F.7 Compressive Strength Test of SCC Mix with CS AND EFBF

Compressive Strength of M$_{30}$ SCC with CS and EFBF

Mix	Average Compressive Strength (N/mm2)
Control Specimen	36.20
30% CS + 0.5% EFBF	37.20
30% CS + 1.0 % EFBF	43.30
30% CS + 1.5% EFBF	33.16

Inference: The compressive strength of SCC was higher than VC with 15% for cube specimens.

F.3.2 Split Tensile Strength Test

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which theconcrete members may crack. Tensile strength of concrete is much lower than its compressive strength. It has been estimated that tensile strength of concrete equals roughlyabout 10 % of compressive strength

Observations:

Table F. 5 Test Results on Split Tensile Strength of SCC Cubes with CNSA AND PPF

Mix	**Average Split Tensile Strength (N/mm2)**
Control Specimen	2.5
30% CS + 0.5% EFBF	2.84
30% CS + 1% EFBF	4.37
30% CS + 1.5% EFBF	3.01

Split tensile strength = $2P/\pi dl$ = 2 ×208×1000/ π×150× 300 = 4.37N/mm^2

Testing of M_{30} SCC Mix and Mix with CNSA ANDPPF

Inference: The split tensile strength should be 2/3 rd of the modulus of rupture.Modulus of rupture = fcr = 0.7 $\sqrt{fck}$ = 0.7 √ 30 = 3.83 N/mm^2

Split tensile strength = 2/3 × fcr = 2/3 × 3.83 = 2.55 N/mm^2