Influence of Self Compacting Concrete Reinforced with Chopped Steel Fiber – A Research Analysis

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ABSTRACT

Self-compacting concrete is a state-of-the-art technology actively used all over the world in the construction field. In this study, we research both combined and individual effects of Self Compacting Concrete Reinforced with chopped Steel Fiber. Fiber reinforced concrete (FRC) is widely practiced with high ductility and sufficient durability. In this study, the properties of the volume fraction and length of steel fiber (SF) on the mechanical properties of FRC were analyzed. This paper provides result data of the compressive strength, and split tensile strength, flexural strength of steel fiber reinforced concrete. For compression test, a result data obtained has been analyzed and related with a control specimen. A relationship between Compressive strength vs. fiber volume fraction and tensile strength vs. fiber volume fraction & flexural strength vs. fiber volume fraction of steel fiber are represented graphically. The addition of fiber enhanced the ductility significantly.

Keywords: self-compacting concrete, chopped, steel fiber, mechanical properties.

INTRODUCTION

Self-compacting concrete, also known as self-consolidating concrete, is characterized by its high fluidity. Thanks to this property, it spreads into concrete formwork with no need for vibration equipment. This non-segregating concrete is distributed by its own weight, while maintaining the properties of regular concrete, such as durability and strength. Some self-compacting concrete mixtures include admixtures like superplasticizer and viscosity modifiers to reduce bleeding and segregation. When concrete segregates, it loses strength and results in honeycombed areas throughout the surface. However, a well designed self-compacting concrete will not segregate thanks to its plasticity and stability.

The high workability is one of the crucial properties for SCC and can be controlled by appropriate dosage of super plasticizer. Fibre Reinforced Concrete (FRC) is defined as a concrete incorporating relatively short, discrete, and discontinuous fibres. It is a concrete which is considered to placed and compacted every part of the corner of the formwork, even in the presence of dense reinforcement, purely by means of own weight and less or no vibrational effort. However, various investigations are moving on in various characteristics of the mechanical behavior and structural applications of SCC. SCC has established to be effective material, so there is a need to guide further investigation on the normalization of self-consolidating characteristics and its behavior to apply on different structural construction, and its usage in all perilous and inaccessible project zones for superior quality control. Several studies have shown that fiber reinforced composites are more efficient than other types of composites. The key determination of the fiber is to restrict cracking and to increase the fracture toughness of the brittle matrix through bridging action in both micro and macro cracking of the matrix. At initial stage and the hardened state, Inclusion of fibers improves the properties of the concrete especially of the high performance concrete like SCC. Hence researchers have focused on study of the strength and durability aspects of fiber reinforced SCC. This mechanism growth is the demand of energy for the crack to propagate. The linear elastic behavior of the matrix is not affected significantly for low volumetric fiber fractions.

The objective of present research is to mix design of SCC of grade M30 and to investigate the effect of inclusion of chopped steel fiber on fresh properties and hardened properties of SCC. The effects of the volume fraction and length of steel fiber (SF) on the mechanical properties of FRC were analyzed. The outcomes indicate that adding SF significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious gain. Furthermore, the length of SF presents an influence on the mechanical properties. Fresh properties comprise flow ability, passing ability, and viscosity related segregation resistance. Hardened properties to be studied are compressive strength, splitting tensile strength, flexural strength, and fracture test.

EXPERIMENTAL STUDY

Materials

Portland slag cement [1] of Konark brand available in the local market was used in the present studies. The coarse aggregate used were 20 mm and 10 mm down size. Natural river sand has been collected from Yamuna River, Sonipat, Haryana and conforming to the Zone-III as per IS-383-1970 [2].Fly ash is used. The Sika Viscocrete Premier from Sika is super plasticizer and viscosity modifying admixture. Steel fiber of length 12mm of 0%, 0.05%, 0.1%, 0.15%, and 0.2% volume fraction by weight of the total weight of concrete was used in the investigations.

Table-1: Mechanical properties of steel fiber

Fiber variety	Length (mm)	Density (g/cm^3)	Elastic modulus(GPa)	Tensile strength(MPa)	Elong. At break (%)
SF	20	0.91-0.95	200-500	500-200	0.5-3.5

Figure-1: Photograph of Chopped Steel Fiber

Experimental Procedures:

The mixing of materials properly mixed in a power operated concrete mixer. Adding coarse aggregate, fine aggregates, cement and mixing it with fly ash properly mixed in the concrete mixer in a dry state for a few seconds. Then the water added and mixing it for three minutes. During this time the air entraining agent and the water reducer are also added. Dormant period was 5mins. To obtain the steel fiber reinforced SCC, the required fiber percentage was added to the already prepared design mix, satisfying the fresh SCC requirements.

Calculation for M30 grade of SCC was done following EFNARC code 2005 in the mix design 15% of fly ash use as a replacement for cement to achieve the target strength. Viscocrete admixture was used to reduce the water content and improve workability as per the requirement for SCC.

Table-2: Adopted Mix Proportions of SCC

Cement (kg/m^3)	Fly Ash (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (kg/m^3)
420.35	63.05	176.54	899.55	596.9	5.044
1	0.15	0.42	2.14	1.42	0.012

Casting of Specimens

Forty two number cubes (150×150×150) mm, forty two numbers cylinders (150×300) mm & forty two numbers prisms (100×100×500) mm were cast and investigations were conducted to study the mechanical behavior, fracture behavior of steel fiber reinforced SCC (SFC).

Tests on Fresh Concrete

To determine the fresh properties of SCC, different methods were developed. Slump flow and V-Funnel tests have been proposed for testing the deformability and viscosity respectively. L-Box test have been proposed for determining the segregation resistance.

Figure-2: (A) Slump flow test, (B) V-Funnel test, (C) L-Box test

Tests on Hardened Concrete

A proper time schedule for testing of hardened SCC specimens was maintained in order to ensure proper testing on the due date. The specimens were tested using standard testing procedures as per IS: 516-1959.

Fracture Test

The ductility can be measured by fracture behavior of FRSCC and to determine fracture energy, prisms specimen of dimension 100mm×100mm×500mm were cast with a notch of 5mm width (n0) and 30mm depth as per the specification of the specimen. The schematic diagram of specimens and loading arrangement of test setup shown in the Fig.3. During testing, Crack Mouth Opening Displacement (CMOD) was noted using through two dial gauges.

Figure-3: Loading Setup for Fracture Test

RESULTS & DISCUSSION

Fresh Concrete Properties

The Table-3 indicates a reduction of flow value owing to inclusion of fibers. The reason for this phenomenon is that a network structure may form due to the distributed fiber in the concrete, which restrains mixture from segregation and flow. The slump flow decreases with increase in fiber percentage. The T50 flow, which was measured in terms of time (seconds) increases as the slump flow value decreases. The decrease in slump value is due to the increase in the percentage of fiber. The L-Box value increases as the slump flow value increases. The increase in slump value is due to the increase in the percentage of fiber as well as the L-Box value also increases. The V-Funnel test & T50 flow, which was measured in terms of time (seconds) & both the value measured are dependent with each other. V-Funnel value and T5 flow increases as the slump flow value decreases. The decrease in slump value is due to the increase in the percentage of fiber.

Hardened Concrete Properties

To compare the various mechanical properties of the FRSCC mixes the standard specimens were tested after 7 days and 28 days of curing. The results are summarized in Table 3. The graph shows the optimum fiber content for maximum strength in mixes with different fibers. The highest 7-day compressive strength was observed for mix with 0.25 %steel fiber and lowest for mix with 0.1% steel fiber. The highest 28-days compressive strength was observed for mix with 0.25 %steel fiber and lowest for mix with 0.3%steel fiber. The highest 28-days split tensile strength was observed for mix with 0.25% steel fiber and lowest for mix with 0.1% steel fiber. The highest 28-days flexural strength was observed for mix with 0.2%steel fiber and lowest for mix with 0.1% steel fiber.

Table- 3: Hardened Concrete Properties of SCC and FRSCC

Mixes	7-Day compressive strength (MPa)	28-days compressive strength (MPa)	28-days split tensile strength (MPa)	28-days flexural strength (MPa)
PSC	42.85	48.22	3.42	12
SFC-1	49.35	54.72	3.54	13.22
SFC-1.5	50.22	60.35	3.80	14.25
SFC-2	50.22	66.13	4.23	17.22
SFC-2.5	52.75	70.44	4.56	15.5
SFC-3	50	53.33	3.93	13.33

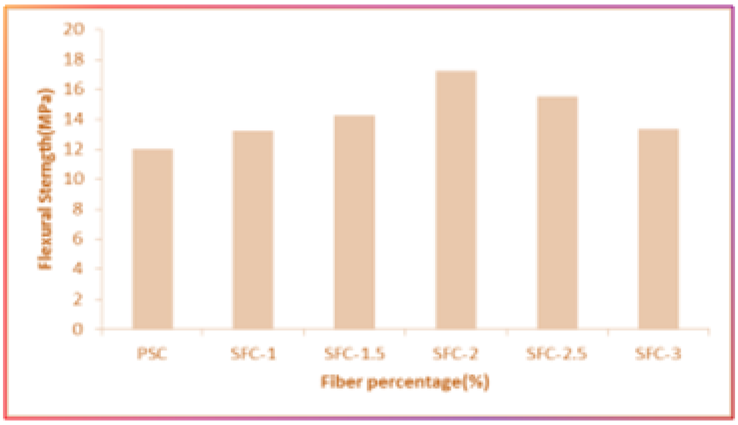

Figure-4: Variation of Flexural strength For Different SCC Mixes At 28days

CONCLUSION

In this article, Addition of fibers to self-compacting concrete causes loss of basic characteristics of SCC measured in terms of slump flow, etc. Addition of fibers to self-compacting concrete improve mechanical properties like compressive strength, split tensile strength, flexural strength etc. of the mix. There was an optimum percentage of each type of fiber, provided maximum improvement in mechanical properties of SCC.

REFERENCES

[1]. Abbas Al-Ameeri, The effect of steel fiber on some mechanical properties of self compacting concrete, American Journal of civil engineering, 2013, Issue 3, pp 102-110.

[2]. B. Kumaran, Vinod Kumar, The effect of addition of lime stone powder on the properties of self compacting concrete International Journal of Innovative Research in Science, Engineering and Technology, 2018, Vol 2, Issue 10..

[3]. B.H.V.Pai, M. Nandy, A. Krishnamoorthy, P.K. Sarkar and C.Pramukh Ganapathy, Experimental Study on self compacting concrete containing Industrial by-products, European scientific Journal, April 2014, Vol.10, pp 292-300.

[4]. Dhiyaneshwaran.S , Ramanathan,.P, Baskar.I and Venkatasubramani.R. Study on durability characteristics of self compacting concrete containing fly-ash. Journal of civil Engineering2013,Vol. 7, Issue 3, pp 342-353.
[5]. Abinaya, J. Jaccilin Santhya, A. Jerina, P. Srinidhi, J.T. Walter, D. Brandon(2017)"Experimental Investigation on Self Compacting Concrete using Light Weight Aggregates."International Journal of ChemTech Research,Vol.10, No.8, pp 517-525.
[6]. S.Barathan, B.Gopinath(2013),"Evaluation of wood ash as a partial replacement of cement."International Journal of Science, Engineering and Technology Research,Vol.2, Issue 10, ISSN: 2278 – 7798.
[7]. P. Ram, Bhaskar, P. Murli, R. Venugopal (March, 2019.). "Performance of Self Compacting Concrete containing different Mineral admixtures" Journal of Civil Engineering,Vol.17, No. 3.
[8]. Bonen, D. and Shah, S. P. (2005). "Fresh and hardened properties of self-consolidating concrete construction." Progress in Structural Engineering Materials, Vol. 7, No. 1, pp. 14-26.
[9]. Chee Ban Cheah ,MahyuddinRamli (2011),"Strength, durability and drying shrinkage of structural mortar containing HCWA as partial replacement of cement" School of Housing, Building and Planning, UniversitiSains Malaysia, 11800 Penang, Malaysia.
[10]. EFNARC (2002). Specification and guidelines for self-compacting concrete, UK, p. 32, ISBN 0953973344.
[11]. Ombira, H., Shiva, K. Mix design for Self compacting concrete. Concrete library of JSCE, No.26, June 2020.
[12]. Sonebi, M. (2004). "Medium strength self-compacting concrete containing fly ash: Modelling using factorial experimental plans." Cement and Concrete Research, Vol. 34, No. 7, pp. 1199-120
[13]. Uysal, M. and Sumer, M. (2011). "Performance of self-compacting concrete containing different mineral admixtures." Construction and Building materials, Vol. 25, No. 11.
[14]. M.Iyappan and Dr.A.Jagannathan, High strength self compacting concrete with nano silica, International Journal of Emerging Trends in Engineering and Development, 2019, Issue 4, Vol 5, pp 163-168.
[15]. Prof. Sivam H.Mahure, Dr. Mohit, Effect of mineral admixture on fresh and hardened properties of self compacting concrete, International Journal of Innovative Research in Science, Engineering and Technology, 2021.