Sustainable Fiber Reinforced Self-Compacting Concrete with Carbon and Glass Fiber Addition And Its Economic and Environmental Significance

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Abstract
Concrete is the most popular material in the construction sector and due to its popularity and use it has become the largest contributor to the environment also. This is primarily due to the fact that production of concrete consumes Portland cement which consumes high amount of energy and considerable CO2 emissions. It becomes mandatory to search for suitable alternatives of cement. Different kinds of industrial by-products, such as wood ash, solid waste incinerator bottom ash, solid waste incinerator fly ash, metakaolin, cement kiln dust, graphene oxide, agro-industrial by-products, electric arc furnace dust, and coal bottom ash, may to some extent replace cement and thereby reduce the environmental impact on the planet earth from the use of concrete as a construction material. Self-compacting concrete (SCC) is a flowable concrete mixture which has been given viscosity through adding up of different forms of admixtures that give the composite flexibility. Because of its extremely fluid nature, this concrete can be used in complicated situations as well as around parts of complex strengthening. SCC is an extremely flowable kind of material that does not need the same amount of mechanical vibration to be put as standard concrete. SCC is non-isolating concrete that moves with flexibility under the influence of gravity, with the adjunct of super-plasticizers and viscosity modifiers.

Keywords: Self compacting concrete; workability; viscosity; carboxylic ether

1. INTRODUCTION
While comparing to the vibrating concrete of the similar fraction, self-compacting concrete has a higher strength and thus provides an improved interface among aggregates and reinforce cement. Self-Compacting concrete can also be presently mounted higher than 5 metres and at a much faster rate than traditional concrete.

Many new test procedures have been developed to assess the new characteristics of Self-
compact Concrete. The slump flow test is the most commonly used field test, and ASTM is in the process of standardising it. After completely filling the slump cone without compacting it, the cone is lifted and the flow of the SCC is measured. The flow rate should be between 18 and 32 inches per second. VSI measures the inability to segregate.

The VSI is determined by whether water can be seen at the edge of the SCC flow or spread, or if aggregates pile near the centre. The VSI scale ranges from 0 to 3, with 0 indicating “highly stable” stability and 3 indicating “unacceptably unstable” stability.

The movement of time taken by the concrete to flow a spread of 20 cm diameter (500 mm) after the instant of the plunge cone is lifted up is used to calculate the viscosity. It is also known as t20 measurement, and it typically ranges from 2 to 10 seconds. A higher T20 value indicates that the SCC fluid is more viscous.

![Figure 1.1 Slump flow Test Apparatus](https://theconstructor.org/concrete/slump)

The U and L boxes are the examinations which allow the SCC to flow all the way to the rebar and check the movement. Several tests for fresh concrete properties are also performed to determine slump flow and L-box values. The slump test is the most commonly used method of determining the consistency of concrete, and it can be performed in a laboratory or on the job site. Slump flow values differ depending on the mix. We have an M30 mix in this, and our slump is about normal. The mix's slump flow value is given as 150mm. As a result, this slump is used to identify the workability values of the mix in various ways, ensuring the uniformity of concrete under different field conditions. It is limited to concrete formed of aggregates smaller than 38mm in size. It must be extremely deformable as well as resistant to bleeding and segregation. Different combination elements, for example regulating the coarse total substance along with element mass gradation, optimising the width/cm, along with using chemical admixtures in addition to mineral additives, could be adjusted to meet such conflicting requirements.

SCC can help to:

1) reduce building period; 2) confirm decent compaction, particularly in overfilled structural foundations or else problematic range zones; 3) cut labour expenses; 4)
remove sound and the menace of worker damage connected by vibration methods; and
5) aid to accomplish sophisticated excellence quality exteriors.

It likewise amplifies the limit climate covers us from. Taking in all phases of creation, concrete is supposed to be liable for 4-8% of the world's CO2. Among materials, just coal, oil and gas are a more prominent wellspring of ozone depleting substances. A big part of solid's CO2 outflows are made during the assembling of clinker, the most-energy escalated a piece of the concrete making measure.

However, other ecological effects are undeniably less surely known. Concrete is a parched behemoth, sucking up right around a tenth of the world's modern water use. This regularly strains supplies for drinking and water system, on the grounds that 75% of this utilization is in dry season and water-focused on locales. In urban areas, concrete likewise adds to the warmth island impact by retaining the glow of the sun and catching gases from vehicle debilitates and climate control system units – however it is, at any rate, better than more obscure black-top.

It additionally demolishes the issue of silicosis and other respiratory infections. The residue from wind-blown stocks and blenders contributes as much as 10% of the coarse particulate matter that stifles Delhi, where analysts found in 2015 that the air contamination record at all of the 19 greatest building locales surpassed safe levels by in any event multiple times. Limestone quarries and concrete plants are additionally regularly contamination sources, alongside the trucks that ship materials among them and building locales. At this scale, even the procurement of sand can be cataclysmic – annihilating so many of the world's sea shores and waterway courses that this type of mining is presently progressively run by coordinated wrongdoing packs and connected with deadly viciousness. Concrete is tipping us into environment disaster.

This addresses the most extreme, yet least comprehended, effect of solid, which is that it annihilates characteristic foundation without supplanting the biological capacities that mankind relies upon for preparation, fertilization, flood control, oxygen creation and water cleaning.

Cement can take our civilisation upwards, up to 163 stories high on account of the Burj Khalifa high rise in Dubai, making living space out of the air. In any case, it additionally pushes the human impression outwards, rambling across ripe dirt and stifling territories. The biodiversity emergency – which numerous researchers accept to be as a very remarkable danger as environment bedlam – is driven basically by the transformation of wild to horticulture, mechanical domains and private squares.
For many years, mankind has been willing to acknowledge this natural disadvantage as a trade-off for the undoubted advantages of cement. In any case, the equilibrium may now shift the other way.

![Figure 1.2 L-box test apparatus](https://m.indiamart.com/proddetail)

**Figure 1.2 L-box test apparatus**

(Source: https://m.indiamart.com/proddetail)

### 2 LITERATURE REVIEW

A detailed review of 40 papers, on self-compacting concrete, published within a period of 2001 to 2017, has been undertaken. The review process is based on the issue wise analysis. A table with papers under particular issues has been included, which would help in understanding some specific findings of each research paper.

The following are research papers reviewed of the proposed topic:

[Beissel, et al, 2001] Joint concrete requires to be installed at its specific weight, The flow rate must be particularly adequate to make it flow beneath its specific weight, which is compulsory to fulfill this type of prerequisite. [30]

[Wenzhong Zhu, et al, 2003] The durability of concrete is highly influenced by the increase and enhancement of defects, which are almost identical to ordinary concrete. However, with the addition of fiber the durability increases as the porosity and durability decrease. [39]

[Brouwers, et al, 2005] SCC prevents splitting by using mineral fibers that help hold the parts together and so that they all have the same viscosity and do not separate under gravity and therefore, facilitate the complete concrete progress. Self-adhesive concrete requires to be applied to its weight, Flow strength must be sufficient to make it drift beneath its specific weight, which is essential to follow in this type of requirement. [19]

[Donom, et al, 2006] analyzed research cases and future work, studies in the area of composite concrete. As technology advances the SCC now undergoes a mixture of fibers, small reinforcement of cement along with silk, lime, and substitutes part of a good combination of fly ash, dust, marble dust to replace part of the excess metal. Even fibers have a variety of crystalline and non-crystalline fibers with elastic and non-elastic properties. Then again the
differences in size affect the physical, mechanical and chemical properties and the size of the wires containing the SCC compound will be investigated. [27]

[El-Dieb, et al, 2008] researched the installation of Fibers and its advantages through its addition in the SCC, Fibers bridges prevent and promote its spread inside the concrete and ultimately increase the strength and strength of concrete flexibility. Tests demonstrate that it is feasible to retain SCC properties whilst employing fiber reinforcement. The high fiber matter that can be applied without altering the concrete flow was revealed in their experiments, and the kind of fiber can significantly affect the adhesive and mud volume. Conventional OPC has been used in standard silica fire tests and sand is used as silk sand. Several tests were performed in the process and apparently studied the impact and percent of fiber without affecting the SCC structures and various types of fibers. [4]

[Ghoddousi, et al, 2009] explored the part of carbon fibers in the development of bonding concrete. Non-crystalline fiber, provides great compressive strength to the compound but flexural strength and bending strength varies due to alignment of fibers. Randomly distributed fibers produce troubles and lowered performance. Superplasticizers along with fly ash as a partial replacement of nearly 30 percent also help out to improve their performance. As most of the materials used are reused and that is why the results are very fruitful giving more energy up to 27% increase in strength for 7 days to 23% increase in strength for 28 days with a mixed economic value. [26]

[Krishna Rao, et al, 2010] studied the technical challenges related to the unevenly distribution of steel fibers in the SCC. Commonly placed in the course of concrete stream, due to this form the strength of concrete improves considerably and by use of fiber and its short-term arrangement could enhance the strength of the beam depending on the path of concrete movement. However, the performance is reduced compared to the standard and that is why large plasticizers are needed in large quantities. [9]

### 3. COST ANALYSIS OF CEMENTITIOUS MATERIALS

| Concrete used with or without fibre | Cementitious material (Cement+Flyash) | Fine aggregate | Coarse Aggregate | Super Plasticizer | Cost (Rs) | Cost analysis |
|-----------------------------------|-------------------------------------|----------------|-----------------|-------------------|-----------|--------------|
| Without fibre (Rs.)               | 900                                 | 700            | 450             | 10                | 2160      |              |
| With glass fibre (360 Rs/kg) (Rs.) | 750                                 | 700            | 450             | 10                | 1910      | 7% Decreases |

Table: 3.1 Cost Analysis of the work (For 1 Cum)
4 DISCUSSION

Result shows that the addition of carbon fibre and glass fibre in SCC increases the compressive strength up to certain limit. Further addition of fibres decreases the compressive strength. So as per the obtained result optimum percentage of fibre in SCC for the compressive strength is 0.8%. 0.8% carbon fibre increases the compressive strength about 13.03% & 18.68 whereas for Glass fibre addition it increases 12.33% & 19.49 at 14 & 28 days respectively. The cost of SCC with glass fibre decreases by 7% and SCC with carbon fibre decreases by 4.5 %. So FRSCC used here is also cost effective.

It also has been noticed that SCC with fibre addition is an environmentally feasible solution as it reduces the cement use in concrete by 8 to 9 %. Also, we may use supplementary cementitious materials like fly ash and silica fume to reduce the environmental impact from it.

5. CONCLUSIONS

1. It has been analysed that the addition of carbon fibre and glass fibre in SCC increases the compressive strength up to certain limit. Further addition of fibres decreases the compressive strength. So as per the obtained result optimum percentage of fibre in SCC for the compressive strength is 0.8%. 0.8% carbon fibre increases the compressive strength about 13.03% & 18.68 whereas for Glass fibre addition it increases 12.33% & 19.49 at 14 & 28 days respectively.

2. Similar observation is obtained from the split tensile strength. Above table indicate that the addition of carbon fibre and glass fibre in SCC increases the split tensile strength up to certain limit. Further addition of fibres decreases the split tensile strength. So as per the obtained result optimum percentage of fibre in SCC for the split tensile strength is 0.8%. 0.8% carbon fibre increases the split tensile strength about 46.42% & 47.59 whereas for Glass fibre addition it increases 40% & 42.16 at 14 days & 28 days respectively.

3. Slightly different result is obtained for the flexural strength. Above table indicate that the addition of carbon fibre and glass fibre in SCC increases the flexural strength up to certain limit. Further addition of fibres decreases the flexural strength. So as per the obtained result optimum percentage of fibre in SCC for the split tensile strength is 1 %. 1 % carbon fibre increases the split tensile strength about 53.36% & 54.92 whereas for Glass fibre addition it increases 44.60% & 46.47 at 14 days & 28 days respectively.

4. Results indicated that the slump flow and L-box is decreases with the addition of fibre in SCC.

5. It is concluded as per the study optimum range of glass and carbon fibre in SCC is 0.8 % to 1%. Carbon fibre improves the compressive strength, Split tensile strength and flexural strength 15%-20%, 60%-65% & 50%-55% respectively whereas glass fibre improves the compressive strength, Split tensile strength and flexural strength 15%-20%, 55%-60% & 45%-50% respectively.

6. The cost of SCC with glass fibre decreases by 7% and SCC with carbon fibre decreases by 4.5%.
%. So FRSCC used here is also cost effective. It also has been noticed that SCC with fibre addition is an environmentally feasible solution as it reduces the cement use in concrete by 8 to 9 %. Also, we may use supplementary cementitious materials like fly ash and silica fume to reduce the environmental impact from it.

6. REFERENCES

[1] A.A. Maghsoudi “Mix design and Mechanical properties of self-compacting light weight concrete” International Journal of Civil Engineering Vol. 9, No. 3, September 2011

[2] Abbas Al-Ameeri. “The effect of steel fibre on some mechanical properties of self-compacting concrete” American Journal of Civil Engineering Vol. 1, No. 3, 2013, pp. 102-110

[3] Antonios Kanellopoulos. “Durability Indicators of SCC” 2nd International RILEM workshop on concrete Durability and Service Life Planning 7-9 September, Haifa, Israel

[4] A.S. Dieb “Flow characteristics and acceptance criteria of fiber-reinforced self-compacted concrete (FR-SCC)” 2011 Elsevier.

[5] Athulya Sugathan “ Self-Compacting Concrete Reinforced with Sisal Fibres” International Journal of latest Technology in Engineering, Management and Applied Science (IJLTEMAS) Volume VI, Issue VII, July 2017, ISSN 2278-2540

[6] Bathum Geeta “A Review: Recent Innovations in Self-Compacting Concrete” International Journal of Scientific & Engineering Research, Volume 4, Issue II, November 2013 ISSN 2229-5518

[7] Biswajit Jena “Study on the Mechanical Properties and Microstructure of Chopped Carbon Fibre Reinforced Self- Compacting Concrete” International Journal of Civil Engineering and Technology (IJCET) Volume 7, Issue 3, may-june 2016, pp. 223-232

[8] Biswajit Jena “Study on Mechanical Properties and Fracture Behaviour of Chopped Steel Fibre Reinforced Self-Compacting Concrete” International Journal of Research in Engineering and Technology ISSN:2319-1163

[9] B. Krishna Rao “Steel Fibre Reinforced Self-Compacting Concrete Incorporating Class F Fly Ash “International Journal of Engineering Science and Technology Vol. 2(9),2010,4936-4943

[10] Chirag Rohilla “A Study on Behaviour of Chopped Fiber Reinforced Self-Compacting Concrete” Volume 1 Issue 12016 ETJ 2016, 1, 33-38

[11] Dhiyaneshwaran, S. “Study on Durability Characteristics of Self-Compacting Concrete with Fly Ash” Jordan Journal of Civil Engineering Volume 7, No. 3, 2013

[12] Dinesh. A, “Experimental Study on Self-Compacting Concrete” International Journal of Engineering Sciences &Research Technology ISSN: 2277-9655 Impact Factor: 4,116

[13] G. Elangovan “Evaluation of Self Consolodating Steel Fibre Concrete (SCSFRC) &its Fresh Properties” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN:2278-1684, p-ISSN:2320-334X, Volume 10,Issue 2(Nov – Dec 2013), PP 06-10

[14] S. A. Bhalchandra “Performance of Steel Fibre Reinforced Self-Compacting Concrete” International Journal of Computational Engineering Research Vol 2. Issue 4

[15] Eduardo N. B. Pareira “Steel Fibre Reinforced Self-Compacting Concrete – Experimental Research and Numerical Simulation 2015-16”

[16] Faiz A. Mirza “Performance of Polypropylene Fibre Reinforced Self Compacting Lightweight Concrete in Hardened State” Fourth International Conference on Sustainable Construction Materials and Technology.SCMT4,Las Vegas ,USA, August 7-11,2016

[17] Gergely A. “The Optimization of the Self-Compacting (SCC) Production Scheduling – Specially the Effect of the Fine Aggregate” IACSIT International Journal of Engineering and Technology, Vol.4, No.4,August 2012

[18] Haddadou N “Fresh and Hardened Properties of Self-Compacting Concrete with
different Mineral additions and Fibres” Build Mater. Struct(2015)2:41-50 ISSN 2353-0057

[19] H J H Brouwers “Self-Compacting Concrete: Theoretical and Experimental Study” Department of Civil Engineering, Faculty of Engineering Technology, University of Twente 2005 Elsevier

[20] Jacek Katzer “Fresh Mix Characteristics of Self-Compacting Concrete Reinforced by Fibre” Periodica Polytechnica Civil Engineering 61(2), pp. 226-231, 2017

[21] Kennouche. S “Formulation and Characterization of Self-Compacting Concrete with Silica Fume” Journal of Engineering and Technology Research, Vol. 5 (5), pp. 160-169, June 2013, ISSN 2006-9790 @ 2013

[22] K.S. Johnsrirani “Experimental Investigation of Self-Compacting Concrete using Quarry Dust” International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013

[23] Mohamed I. Abukhashaba “Behaviour of Self-Compacting Fibre Reinforced concrete containing cement kiln dust” Alexandria Engineering Journal (2014) 53, 314-354

[24] Mounir M. Kamal “Mechanical properties of self-compacted fibre concrete mixes” Housing and Building National Research Center, HBRC Journal (2013)

[25] Osman Gencel “Workability and Mechanical Performance of Steel Fibre Reinforced Self-compacting Concrete with Fly Ash” Composite Interfaces 18(2011) 169-184

[26] P. Ghoddousi “A Model for Estimating the Aggregate Content for Self Compacting Fibre Reinforced Concrete (SCFRC)” International Journal of Civil Engineering, Vol. 8, No. 4, December 2010

[27] P.L. Domone “A Review of the hardened mechanical properties of self-compacting concrete” Cement and Composites 29 (2006) 1-12

[28] P. Muthupriya “Strength study on fibre reinforced self-compacting concrete with fly ash and GGBFS” International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 03, No. 02, April 2014

[29] Prasad M L V Prasenjit Saha “Eco-efficient Fibre Reinforced Self-compacting Concrete for Replacements of Cements and Natural Sand with Waste Materials” International Journal of Earth Sciences and Engineering ISSN 0974-5904, Volume 09, No. 03 June 2016, P.P. 71-77

[30] R. Beissel “Self-compacting concrete: modern concrete and admixture technology” 26th Conference on Our World in Concrete & Structures: 27-28 August 2001, Singapore.

[31] R Bharathi Murugan “Influence of Glass Fibre on Fresh and Hardened Properties of Self Compacting Concrete” IOP Conf. series: Earth and Environment Science 80 (2017) 012004

[32] S. Brundha “Fresh and Durability Studies of Polypropylene Fibre Reinforced Self-Compacted Concrete (SCC)” International Journal of Science, Technology and Management Volume No. 04 Special Issue No. 01. March 2015 ISSN 2394-1537

[33] S. Grunewald “Improved Tensile Performed with Fibre Reinforced Self-Compacting Concrete” G. J. Parra-Montesinos, H. W. Reinhardt, and A.E. Naaman (Eds.): HPFRCC 6, pp. 51-58

[34] Sholihin AS’AD “Fresh State Behaviour of Self Compacting Concrete Containing Waste Material Fibres” The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction. Procedia Engineering 14 (2011) 797-804

[35] Siddarth Anand “Effect of Steel Fibre on Self-Compacting Concrete: A Review” International Research Journal of Engineering and Technology (IRJET), Volume 03 Issue: 03, Mar 2016 e-ISSN:2395-0056, P-ISSN:2395-0072

[36] S. Nandhini “A Study on Hybrid Fibre Reinforced Self-Compacting Concrete” SSRG International Journal of Civil Engineering–Special Issue-April 2017, ISSN: 2348-8352

[37] Thomas Paul “Experimental Study on Self-Compacting Concrete with Steel Fibre Reinforcement” International Journal of Science, Engineering and Technology Research (IJSETR) Volume 5, Issue 4, April 2016

[38] Tomasz Ponikiewski “Properties of Steel Fibre Reinforced Self-Compacting Concrete for Optimal Rheological and Mechanical Properties in Precast Beams” Concrete and
Concrete Structures 2013 Conference, Procedia Engineering 65(2013) 290-295

[39] Wenzhong Zhu “Permeation Properties of Self-Compacting Concrete” Cement and Concrete Research, 2003, 33(6), 921-926 DOI: 10.1016/S0008-8846(02)01090-6

[40] Yeong-Nain Sheen “Engineering Properties of Self-Compacting Concrete Containing Stainless Steel Slags” Sustainable Development of Civil, Urban and Transportation Engineering Conference, Procedia Engineering 142(2016) 79-86