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Recent Devolopments in Fibrous Self Compacting Concrete-A Review

S. Vijaya Kumar[1], B.L.P.Swami[2], S. Suganya[3] and C.Chandana priya[4]
[1]Associate professor, Civil Engineering Department , Vasavi college of Engineering, Hyderabad 500032,(T.S) (India).
svijayakumar74@gmail.com
[2]Professor Civil Engineering Department, Methodist college of Engineering and Technology, Hyderabad-(T.S) - (India).
blpswamy@yahoo.com
[3-4]Assistant professor, Civil Engineering Department, Methodist college of Engineering and Technology, Hyderabad(T.S)-(India).er.suganya11@gmail.com, chandana.chavali@gmail.com

***Abstract*—Self compacting concrete (SCC) is generally defined as the concrete that does not need Compaction. The use of SCC in actual construction is giving importance because of various advantages .The use of S.C.C is becoming popular in India and it is being put to use in major construction projects. The present article attempts to review and summarize the research work that has been carried out in the area of SCC. After discussing the back ground, the recent research investigations that have been carried out on SCC by Dr.B.L.P.Swami, Dr.B.Dean Kumar and S.Vijaya Kumar are discussed in details and the conclusions are drawn.**

***Index Terms*— SCC, Flowability, Workability ,Viscosity, Triple blending , Fibers ,CompressionFlexure.**

I. INTRODUCTION

A. Development of Self Compacting concrete

Development of Self Compacting concrete(SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast in place concrete .SCC is innovative to flow under its own weight completely filling the voids in the form work and achieving full compaction even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as a traditional vibrated concrete.

B. Production of SCC

S.C.C consists of same ingredients as conventional concrete which are ordinary Portland cement (OPC), aggregates and water. Mineral and chemical admixtures are added to obtain the required flow properties of S.C.C. Usually , the chemical admixtures which are added consist of high range water reducers (Super plasticizers) and viscosity modifying agents which change the rheological properties of concrete S.C.C mixes are designed and tested for flow properties before use.

C. Advantages of S.C.C

S.C.C has become an advanced construction material S.C.C does not require vibration to attain full

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compaction resulting in reduction of site man power, better surface finishes, easier placing, high strength, better durability and lower overall costs etc. S.C.C is better suited than conventional concrete for almost all the structural applications like bridges, box culverts, buildings, tunnel linings, dams, diaphragm walls, structural joints etc.

II. Review Of Earlier Work on S.C.C

S.C.C, right form its innovation has under gone various improvements to suit the various needs. Several researchers worked on S.C.C and brought it to the modern stage. Further work is still being carried out on S.C.C to make it into a most useful construction material and versatile. The following gives the details of developments which have taken place on S.C.C in various stages.

A. Early innovative work on S.C.C

Okamura, H.Y, Ouchi, M.I (34) did the pioneering work in Japan towards the end of 20th century in the development and the practical uses of S.C.C .This work was mainly carried out to over come the problems of concrete workers and labour Ouchi , M. and M.Hibino (35) carried out investigations on the production and applications of S.C.C. Earlier Ozawa,K(36) worked on durability aspects of high performance concrete (HPC). Gomes, P.C.C et al (17)have conducted experimental work for optimizing the high strength S.C.C . The authors suggested to use 12mm aggregate size, with condensed silica fume (CSF) at 10% and the water to cement ratio of 0.4. Khayat, K.H et al (27) studied the workability, listing and performance of S.C.C. Nan Su Kung et al (31) had suggested a simple mix design procedure for S.C.C The European project group (EFNRC, 2002)gave the specifications and guidelines for S.C.C. The methods for testing the workability of S.C.C and the principles of mix design were suggested. Peterson, O et al(37)studied the workability of S.C.C and suggested a model for the production of S.C.C. Jagadish, v et al (24) studied the proportioning of S.C.C mixtures. Khatri,R.P et al (28) studied the effect of different supplementary materials on the mechanical proportions of S.C.C with normal concrete. Domone, P.I(12) reviewed the mechanical properties of hardened S.C.C. Buia,V.K et al (9)gave report listing methods for studying the segregation resistance of S.C.C.
The A.C.I publication 544(1) gives the state of the art report on fiber reinforced concrete (FRC). Narayanan et al (32) studied the various factors which influence the workability of FRC. Heurikstrnag et al (18) gave classification of fiber reinforced cementitious materials for structural applications. Majumdar et al (29) gave the details of glass fiber reinforced cement in their publication. A.Sivakumar and Manu Santhanam (40) gave the Mechanical properties of FRC reinforced with metallic and non- metallic fibers . khatri, R.P et al (28) studied the effects of different supplementary cementitious materials on mechanical properties of HPC. Sravama, P, Srinivasa Rao, P and Seshadrisekhar (41) reported the results of glass fiber reinforced S.C.C slabs under flexure. Christina Frazero et al(11) studied the durability of steel fiber reinforced S.C.C with ordinary FRC .Melgorzata pajak et al (30) used hybrid steel fibers in S.C.C tested under flexure and reported the results . Dr Mrs S.A. Bhalchandra et al (7) studied the performance of steel fiber reinforced S.C.C. Athiyamaan, V et al (5) gave a state of the art report containing the statistical detailed analysis of fiber reinforced self compacting concrete . The effect of silica fume on the proportion of steel fiber reinforced S.C.C was studied by Ahmed Fathi Mohamed et al (4) .Satheskumar , K (39) et al compared steel and basalt fibers used in S.C.C.

III. Recent Investigations on Fibrous SCC

A. Triple blended SCC with steel fibers

[1] Vijaya Kumar, S, [2] Swami, B.L.P et al(43) conducted experiments in the concrete laboratory (Vasavi college of Engineering) on triple blending by replacing OPC with 15%fly ash and 10% condensed silica fume . Two S.C.C mixes of grades M_{25} and M_{30} were designed. Short steel fibers with three aspect ratios (15, 20and 25) were used at three percentages (0.5, 0.75and 1.0). In total trial 11 combinations including two basic combinations were trail in designed concrete mixes M_{25} and M_{30}. The mixes were tested for workability with the usual chemical admixtures (Superplasticizer and VMA). The various flow properties were found to satisfy the EFNARC specifications. Specimens were cast and tested at the age of 28 days for compression , split tension and flexure .The results presented in tables 1 and 2 and figures 1 and 2 may be referred from paper 43.
The authors concluded that up to certain maximum percentage fibers are contributing to strength. The triple blending is advantageous with the presence of fibers the cracking and ductility characteristics of S.C.C are

improved .The authors continued the investigations with Metakaoline (metacem) instead of CSF and gave the results (44).The authors suggested an optimum percentage of 0.4 percent of steel fibers with an aspect ratio of 25 to give better results. Triple blended S.C.C of M_{50} grade using 20% fly ash and 10% Metakaoline was used as replacement to OPC to give optimum results. It was also concluded that CSF or Metakaoline are giving similar results.

B. Investigations on the influence of fiber percentage and aspect ratio on the elastic properties of fibrous SCC

Vijaya Kumar and Swami .B.L.P et al conducted studies on the elastic properties of fibers S.C.C (45) Four fiber percentages were tried at 0.1,0.2,0.3 and 0.4 .The aspect ratios of 10,20 and 30 Equivalent SCC mix of M_{40} grade was used 10% CSF with 20% fly ash was used as replacement to OPC in triple blending .After satisfying the workability criteria ,tests were conducted for Compressive strength , Young's modulus and poissons ratio .

The authors recommended optimum values of 0.4% steel fiber with aspect ratio of 20 to give the highest Young's modulus and lowest poissons ratio. The results presented in table 3 and figures 3 and 4 may be referred from paper 45.

C. Work carried out on mixed fibrous SCC

Vijaya Kumar and B.L.P. Swami et al (48) conducted experimental investigations on SCC reinforced with mixed fibers (steel and polypropylene). Steel and polypropylene were used at different percentages in a given total fiber percentages which is varied as 0.05,0.10,0.15 and 0.20 M_{40} grade equivalent S.C.C with triple blending (20%fly ash +10% CSF) was used. Tests for mechanical properties were conducted after satisfying the workability requirements. From the results (Table.3), the authors concluded that highest strengths are recorded with 0.2% steel fibers at an aspect ratio of 15. Non metallic fibers contributed towards better ductility and resistance to cracking. In an earlier investigation the authors used glass fiber instead of polypropylene in the mixed fibers .The results are similar to the above.

D. Acid Resistance studies on triple blended fibrous S.C.C

Vijaya Kumar.S and Swami.B.L.P et al (49) studied the acid resistance characteristics of triple blended fibrous S.C.C. Fibrous triple blended S.C.C of M_{50} equivalent grade specimens were cast . Fly ash and CSF were used at20% and 10% replacement of OPC respectively in the mix . Steel fibers of constant aspect ratio of 20 were used at four percentages of 0.1,0.2,0.3 and 0.4 . After satisfying the workability requirements, specimens were cast and cured for 28 days . The specimens were immersed in 5% HCL and H_2SO_4 solutions and were tested at exposed periods of 0,7,14,21 and 28 days . Tests were conducted for weight loss and compressive strength at various exposure periods and the results were discussed.

The authors concluded that triple blending helps to reduce the weight loss when exposed to acid , steel fibers reduce the loss of weight considerably when exposed to acids .P_H value increases in the case of triple blending. Fibers are making the P_H value higher. The results presented under 3.3 and 3.4 may be referred from paper 48 and 49.

E. Permeability and impact properties of fibrous SCC with mineral admixture.

Specimens of equivalent triple blended fibrous S.C.C were cast after workability tests, cured for 28 days and tested for permeability and impact properties. The percentages of steel fibers tried were 0.1,0.2,0.3 and 0.4. The aspect ratios of the fibers were also varied 10, 15, 20 and 25.The impact test was conducted by drop hammer as per ACI 544 2R. Impact test was conducted after 28 days curing by applying specified number of blows like ,0, 50,100,150 and 200. After impact each set was tested for compressive strength. For permeability, RCPT tests were conducted on cylindrical specimens (150 mm diameter and 50mm height each) and the charge was measured to indicate the permeability by the authors(50).

The authors concluded that in the case of triple blended fibrous S.C.C the properties like flow of concrete, impact strength and impermeability were improved considerably compared to plain S.C.C. Fibrous S.C.C with steel fibers at 0.4% with an aspect ratio of 25 has recorded not only the optimum impact strength but also less permeability. Triple blending helped in reducing permeability. The results presented under 3.5 may be referred to paper 50.

IV. Overall Comments

On the basis of the overall review conducted the following comments are made broadly.

1. Triple blending of S.C.C with mineral admixtures contributes towards better flow, higher strength, economy and better durability.
2. Short discrete steel fibers at lower percentages and aspect ratios help in better strength. Crack resistance, durability and better impermeability as well as acid resistance.
3. Mixed fibers help in ductility and prevention of micro cracks.

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