IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 52-61

A Review on Literature of Fiber Reinforced Concrete with Silica Fumes

[1]Sandeep R. Gaikwad, [2]Dr. A. Z. Chitade
Research Scholar Gondwana Univercity, Gadchiroli - 442605, India
Correspondence should be addressed to S. R. Gaikwad; deepta21@rediffmail.com
Director of Board of Examinations and Evaluation Gondwana Univercity, Gadchiroli - 442605, India
Correspondence should be addressed to Dr. A. Z. Chitade; a.chitade@gmail.com

Abstract: *In recent years, an emerging technology termed, "Fiber-Reinforced Concrete (FRC)" has become popular in the construction industry. The materials used in FRC depend on the desired characteristics and the availability of suitable local economic alternative materials. Concrete is a common building material, generally weak in tension, often ridden with cracks due to plastic and drying shrinkage. The introduction of short discrete fibers into the concrete can be used to counteract and prevent the propagation of cracks. Despite an increase in interest to use FRC in concrete structures, some doubts still remain regarding the effect of fibers on the properties of concrete. This paper presents the most comprehensive review to date on the mechanical, physical, and durability-related features of concrete. Specifically, this literature review aims to provide a comprehensive review of the mechanism of crack formation and propagation, compressive strength, modulus of elasticity, stress–strain behavior, tensile strength (TS), flexural strength, drying shrinkage, creep, electrical resistance, and chloride migration resistance of FRC. In general, the addition of fibers along with silica fumes in high-performance concrete has been proven to improve the mechanical properties of concrete, particularly the TS, flexural strength, and ductility performance. Furthermore, incorporation of fibers in concrete results in reductions in the shrinkage and creep deformations of concrete. However, it has been shown that fibers may also have negative effects on some properties of concrete, such as the workability, which get reduced with the addition of steel fibers.*

Keywords: *Compressive Strength, Flexural Strength, Aspect Ratio, Steel Fiber, Percent of Fiber Content, Silica Fume, Workability.*

I. Introduction

Application of Fiber Reinforced Concrete (FRC) is continuously growing in various application fields. FRC is widely used in structures. Due to the property that fiber enhances toughness of concrete, FRC is used on large scale for structural purposes. The fiber is described by a convenient parameter called aspect ratio. The aspect ratio of the fiber is the ratio of its length to its diameter. The principle motive behind incorporating fibers into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation characteristics of the resultant composite. For FRC to be a valuable construction material, it must be able to compete economically with existing reinforcing system. FRC composite properties, such as crack resistance, reinforcement and increase in toughness are dependent on the mechanical properties of the fiber, bonding properties of the fiber and matrix, as well as the quantity and distribution within the matrix of the fibers. It improves fatigue resistance makes crack pattern distributed. By making crack pattern distributed, it is meant that it decreases the crack width. Underground tunneling has a very vast and profound application of SFRC and there is growing interest in SFRC as compared to plain concrete. Rehabilitation of conventional rock bolt and wire mesh support can very disruptive and expensive. The excavations being concrete immediately are increasing. The incorporation of steel fiber reinforcement into the concrete is an important factor in this escalating use, since it minimizes labor intensive process of wire mesh installation. Trials and observations suggest that concrete can provide effective support in mild rock burst conditions.

Balaguru P. et al (1986), in their paper entitled **'Flexural behavior of slurry infiltrated fiber concrete (SIFCON) made using condensed silica fume,'** have presented the results of an experimental investigation on the behavior of slurry infiltrated fiber concrete (SIFCON) prisms (beams) subjected to static and cyclic flexural loading. Altogether, 60 prism specimens were tested. The fibers used were steel fibers with hooked ends. The volume content of fibers varied from 4 percent to 12 percent. The fiber lengths were 30 mm, 40 mm, 50 mm and 60 mm. The slurry was made with and without silica fume. A high-range water reducing admixture (superplastisizer) was used in order to obtain flowing slurry. The water/cement ratio was maintained at 0.30. The cube strength of slurry with silica fume averaged to 71.43 MPa. The slurry without silica fume had average cube strength of 54.2MPa. The authors have concluded that the results of this investigation indicate that a very high flexural strength, in the oder of 69 MPa can be obtained using SIFCON. The prisms (Beams) are extremely ductile both under static and cyclic loading. The addition of silica fume increases the flexural strength. The percentage (magnitude) of increase is the same as the increase in the compressive strength of the slurry. Silica fume has no noticeable effect on the ductility of the beams.

Lakshmipathy. et al (1986) Presented **'Results of SFRC frame Testing'** conducted at Anna University. Two frames, representing a 7 level single bay frame, were constructed at 1/4 scale; one frame was made out of reinforced concrete and the other out of SFRC. Fibers with a length of 1.57-in (40-mm) and an aspect ratio of 100 were used at a volume fraction of 1%. An earthquake loading was simulated by applying load via hydraulic jacks at the 7th, 5th and 3rd levels of the frame. It was found that the SFRC frame had a ductility increase of 57% and a 130% increase in cumulative energy dissipation in comparison to the conventional joint.

Srinivasalu. et al (1987) examined that the **dynamic behaviour of reinforced concrete beams with equal tension and compression reinforced and varying percentages of steel fibers was studied at SERC.** The test beams were subjected to particular static loads those simulated different levels of cracking before they were subjected successively to steady state forced vibration tests. Dynamic flexural rigidity and damping were from the data collected from the test. Tests show that that the dynamic stiffness of SFRC beams in the uncracked state was only marginally high (15% for a fiber volume content of 1%) than for reinforced concrete beams. However large increase in stiffness in the post cracking stage was observed: but this was nearly the same for all the fiber volumes studies (0.5% to 1%). The damping values exhibited by SFRC beams showed significant scatter. Researchers concluded that the average in the uncracked state, applicable to design of machine foundation is 1% critical. Equation are also formulated from the test results to estimate the dynamic stiffness in the beams in post cracking stage for use in the designs involving SFRC elements in blast and earthquake resistant structures. Tests concluded on SFRC specimens by Jacob et al at Institute of Material and Structure Research, Yugoslavia also showed that the inclusion of fibers improve the dynamic properties of concrete. It is also found that resistance to blow fatigue is improved by the addition of fiber. Resistance to blow was investigated using the charpy stricking pendulum an improvement in toughness was reported.

Ramakrishnan V. et al (1989), in their paper entitled **'Flexural behavior and toughness of fiber reinforced concrete'** have presented the results of an extensive investigation to determine the behavior and performance characteristics of the most commonly used fiber reinforced concretes (FRC) for potential airfield pavements and overlay applications. A comparative evaluation of static flexural strength is presented for concretes with and without four different types of fiber: hooked-end steel, straight steel, corrugated steel and polypropylene. These fiber were tested in four different quantities (0.5, 1.0, 1.5 and 2.0 percent by volume), and the same basic mix proportions were used for all concretes. The test program included (a) fresh concrete properties, including slump, ve-be time, inverted cone time, air content, unit weight and concrete temperature and hardened concrete properties; (b) static flexural strength, including load deflection curves, first crack strength and toughness, toughness indexes and post-crack load drop; and (c) pulse velocity. In general, placing and finishing concretes with less than 1 percent by volume for all fibers using laboratory-prepared specimens was not difficult. However, the maximum quantity of hooked-end fibers that could be added without causing balling was limited to 1 percent by volume. Corrugated steel fibers (Types C) performed the best in fresh concrete; even at higher fiber contents (2 percent by volume), there was no balling, bleeding, or segregation. Higher quantities (2 percent by volume) of straight steel fibers caused balling and higher quantities of polypropylene fibers (2 percent by volume) entrapped a considerable amount of air.

The authors have concluded that, compared with plain concrete, the addition of fibers increased the first crack strength (15 percent to 90 percent), static flexural strength (15 percent to 129 percent), toughness index, post crack load-carrying capacity, and energy absorption capacity. Comparing with an equal 1 percent by volume basis, the hooked-end steel fiber contributed to the highest increase and the straight steel fiber provided the least (but appreciable) increase in the above-mentioned properties.

Bayasi Z. et al (1989), Studied **Optimum use of Pozzolanic materials in steel fiber reinforced concrete.** They carried out the effects on fresh and hardened material properties for fly ash caused by substituting cement with fly ash and silica fume in steel fiber reinforced concrete were studied experimentally. The percentage substitution of cement ranged from 0 to 40% and from 0 to 20% for silica fume. The workability of fresh fibrous mixtures was characterized by measuring the inverted slump cone time. The hardened material was tested at 28 days under compression and flexural loads. The development of compressive strength with time was also assessed in steel fiber reinforced concrete incorporating fly ash. The generated test data were used to decide the optimum ranges of cement substitution with fly ash or silica fume in steel fiber reinforced concrete for achieving desirable fresh mix and hardened material characteristics.

Soroushian P. et al (1991), in their paper entitled **'Fiber-type effects on the performance of steel fiber reinforced concrete'** have presented the results of an experimental study on the relative effectiveness of different types of steel fiber in concrete. A constant fiber volume fraction of 2% was used throughout this investigation. The fresh fibrous mixes were characterized by their slump, inverted slump-cone time and subjective workability, and the hardened materials by their compressive and flexural load-deformation relationships. The authors have concluded that the overall workability of fresh fibrous mixes was found to be largely independent of the fiber type. The crimped fibers have produced only slightly higher slumps. Hooked fibers were found to be more effective than straight and crimped ones in enhancing the flexural and compressive behavior of concrete. Under flexural loads, crimped fibers were slightly less effective than straight ones in improving the strength and energy absorption of concrete.

Soroushian P. et al (1991), in their paper entitled **'Latex modification effects on the impact resistance and toughness of plain and steel fiber reinforced concrete'** have investigated the effects of latex modification and steel fiber reinforcement on the impact resistance and flexural strength and toughness of concrete materials. Two levels of latex content and two different fiber volume fractions were considered. Latex modification was particularly effective in increasing the impact resistance of plain concrete. Flexural strength was also increased in the presence of latex, but the flexural toughness of plain concrete did not receive major benefits from latex modification. Steel fibers were effective in increasing the impact resistance and flexural strength and toughness of concrete. The advantages associated with the joint use of steel fiber reinforcement and latex modification on the impact resistance, flexural strength and toughness characteristics of concrete materials are addressed. In conclusion the authors have presented the hypothesis that the improved adhesion capacity and ductility of concrete matrices incorporating latex polymers make them more compatible with steel fibers. The combined action of steel fibers and latex polymers produces the best performance characteristics. In the case of impact resistance and flexural toughness, the joint effects of latex and steel fibers are more than additive, indicating a positive interaction between the two. Latex modification seems to make concrete matrices more compatible with steel fibers. The increase in fiber-to-matrix bond in the presence of latex also seems to enhance the reinforcement properties of concrete.

Sustersic J. et al (1991), in their paper entitled **'Erosion-abrasion resistance of steel fiber reinforced concrete'** have discussed the results of investigation on the erosion-abrasion resistance according to CRD-C 63-80 test method and abrasion resistance according to Bohme test method of steel fiber reinforced concrete specimens. They have used nine mix proportions. The w/c ratios were varied from 0.30 to 0.65. The volumetric percentage of hooked steel fibers were varied from 0.25 to 2.0 vol. percent at the w/c of 0.30 and at the others the quantity of fibers was constant. In addition, mixes without fibers were made at each w/c. The authors have concluded that adding steel fibers into the concrete improves the resistance as measured by both test methods. The erosion-abrasion resistance is improved by an increase of compressive strength and by an increase in fiber content. It can be correlated to improvements of abrasion resistance from the Bohme test method but only at constant w/c and different content of fibers.

Lin Showmay Hsu. et al (1994), Studied **Stress-Strain Behavior of Steel-fiber High- Strength Concrete under Compression.** They were conducted a series of compression tests on 3 x 6-in. cylindrical specimens using a modified test method that gave the complete stress-strain behavior for high-strength steel-fiber concrete with or without tie confinements. The volume fractions of steel fiber in the concrete were 0, 0.5, 0.75, and 1 percent, respectively. Empirical equations are proposed herein to represent the complete stress-strain relationships of high-strength steel-fiber concrete with compressive strength exceeding 10,000 psi. Various parameters were studied, and their relationships were experimentally determined. The proposed empirical stress-strain equations have been compared to actual cylinder tests under axial compression and were found to be in good agreement.

Khedr Safwan A. et al (1994). Studied **Characteristics of Silica-Fume Concrete.** The program investigated various characteristics of silica-fume concrete. It emphasized the effect of silica fume on workability level and its maintenance of fresh concrete; strength development, strength optimization and elastic modulus of hardened concrete; and chemical and mechanical durability of mortar. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. It also included two mixes with 15% silica fume added to cement in normal concrete. Durability of silica-fume mortar was tested in chemical environments of sulfate compounds, ammonium nitrate, calcium chloride, and various kinds of acids. It was found that there was an optimal value of silica-fume content at which concrete strength improved significantly. Due to the slow development of pozzolanic effect, there was a drop in early strength up to seven days and late significant gains up to 56 days upon introducing silica fume to concrete. Elastic modulus, toughness, and steel-concrete bond increased at the optimum silica-fume content in concrete. Silica-fume mortar exhibited significant improvement in durability against chemical attacks of most salts and acids. The improvement was moderate in the case of sulfate compounds. Mechanical erosion resistance increased moderately in silica-fume concrete.

Nataraja. C. et al (1998 & 1999). Studied **Steel fiber reinforced concrete under compression and Stress-strain curve for steel fiber reinforced concrete in compression.** They have proposed an equation to quantify the effect of fiber on compressive strength of concrete in terms of fiber reinforcing parameter. In their model the compressive strength ranging from 30 to 50 MPa, with fiber volume fraction of 0%, 0.5%, 0.75% and 1% and aspect ratio of 55 and 82 were used. In all the models only a particular w/c ratio with varying fiber content was used. The absolute strength values have been dealt with in all the models and thus are valid for a particular w/c ratio and specimen parameter.

Banja. et al (2001) Studied **Investigation on the compressive strength of silica fume concrete using statistical methods.** They studied the effect of silica fume on the tensile and compressive strength of high performance concrete (HPC). They developed mathematical model using statistical methods to predict the 28-day Compressive strength of silica fume concrete with water-to cementations material (w/cm) ratios ranging from 0.3 to 0.42 and silica fume replacement percentages from 5 to 30. They have developed relationship between compressive strength and fiber reinforcing index that predicts 28-day compressive strength at any fiber content in terms of fiber reinforcing parameter and at any water-to-cementations material ratios.

Yoon-Keun Kwak. et al (2002). Studied **Shear Strength of Steel Fiber-Reinforced Concrete Beams without Stirrups.** They were conducted a tests on reinforced concrete beams with three steel fiber-volume fractions,0,0.5,0.75%,three shear span-depth ratios 2,3 and 4 and two compressive strengths 31 and 65 Mpa. The results demonstrated that the nominal stress at shear cracking and the ultimate shear strength increased with increasing fiber volume, decreasing shear span-depth ratio, and increasing concrete compressive strength. As the fiber content increased, the failure mode changed from shear to flexure.

Gopalakrishnan. et al (2003) Structural Engineering Research Centre (SERC), Chennai have studied **'The properties of steel fiber reinforced concrete'** namely the toughness, flexural strength, impact resistance, shear strength ductility factor and fatigue endurance limits. It is seen from the study that the thickness of the Steel Fiber Reinforced Concrete (SFRS) panels can be considerably reduced when compared with weld mesh concrete. The improvements in the energy absorption capacity of SFRS panels with increasing proportions of steel fibers are clearly shown by the results of static load testing of panels. This investigation has clearly shown that straight steel fibers of aspect ratio 65 can be successfully used in field application.

Damgir R.M. et al (2003), in their paper entitled, **'Effect of silica fume and steel fiber composite on strength properties of high performance concrete'** have experimentally studied effect of silica fume and steel fiber composite. The strength characteristics like compressive strength, spilt tensile strength, flexural strength and shear strength have been estimated for seven different mixes. They have also studied properties of green concrete. The authors have concluded that

1) Wet density of concrete increases while workability of concrete decreases with addition of silica fume and steel fibers.
2) The maximum increase in compressive strength was found for mix containing 10% silica fume and 1% steel fibers. It is about 43% for 28 days results.
3) The maximum increase in 28 days split tensile, shear and flexural strengths is 41%, 43% and 47% respectively for mix containing 10% silica fume and 1% steel fibers. Hence it can be concluded that 10% silica fume and 1% steel fibers in composite give optimum results.
4) Load deflection curve indicated that the load required to produce the same amount of deflection is more in steel fiber reinforced concrete as compared to control mix.
5) Addition of steel fibers changes brittle nature of concrete to more ductile one.

Yu-Cheng Kan. et al (2003). Studied **An Investigation on Toughness of Steel Fiber Reinforced Heavy Concrete.** They presented an experimental study dealing with the toughness of heavy concrete based on the ASTM C1018.Mixtures included 0%, 0.5%, 1.0% and 1.5% of steel fiber content by volume are designated, which are all developed according to a mixture used in Kuosheng nuclear power plant in Taiwan. Metallic aggregates of iron shots and iron ore take 48.8% by volume in that mixture. Test results revealed that the tensile strength, rupture modulus and bond strengths appeared increasing with the increase of steel fiber content, while the compressive strength and modulus of elasticity turned out a bit decreasing. Flexural toughness tests showed that the toughness of heavy concrete grew with the steel fiber fraction.

Patnaikuni Indubhushan. et al (2004) in his paper entitled **'Fiber reinforced high performance concrete and its properties'** have discussed production of high strength steel fiber reinforced concrete and properties in compression and bending. He has used three types of enlarged end steel fibers with rectangular cross section. He has studied stress strain properties and failure mode. He has discussed safety design considerations and ductility and serviceability considerations for high strength SFRC.

The authors has concluded that

1) For workable high strength SFRC, a proper slump is between 20 and 60 mm and time of flow through inverted cone ranges from 20 to 40 seconds.
2) The steel fibers with 1% volume do not significantly affect strain at peak stress.
3) The steel fibers influence the strain at 80% peak stress in the descending portion of the curve significantly.
4) The steel fibers significantly increase the ductility of concrete. They increase flexural rigidity HSC beam before yield stage. The load-central displacement ratio is improved by 21.6%, 30.0% and 5.8% by addition of 1% steel fibers of type I, II and III.
5) Steel fibers can increase the displacement of beam at failure. The fibers with small size are much better for improving the flexural rigidity.
6) Steel fibers reduce crack number and size at the comparable load level.

Song P.S. et al (2004) studied **Mechanical properties of high-strength steel fiber-reinforced concrete.** They have observed brittleness with low tensile strength and strain capacities of high strength concrete can be overcome by addition of steel fibers. The steel were added at the volume of 0.5%, 1.0%, 1.5% and 2.0%. The compressive strength of fiber concrete reached a maximum at 1.5%volume fraction and resulted in 15.3% improvement over the HSC. The split tensile and Flexural Strength improved 98.3% and 126.6% at 2.0% volume fraction. Strength models were developed to predict the compressive strength with split and flexural Strength of the fiber reinforced concrete.

Yin-Wen Chan. et al (2004). Studied **Effect of silica fume on steel fiber bond characteristics in reactive powder concrete.** They have carried out , the effect of silica fume on the bond characteristics of steel fiber in matrix of reactive powder concrete (RPC), including bond strength, pullout energy, etc., are presented. The experimental results on steel fiber pullout test of different conditions are reported. Various silica fume contents ranging from 0% to 40% are used in the mix proportions. Fiber pullout tests were conducted to measure the bond characteristics of steel fiber from RPC matrix. It is found that the incorporation of silica fume can effectively enhance the fiber–matrix interfacial properties, especially in fiber pullout energy. It was also concluded that in terms of the bond characteristics, the optimal silica fume content was between 20% and 30%, given the conditions of the experimental program. The micro structural observation confirms the findings on the interfacial-toughening mechanism drawn from the fiber pullout test results.

R. D. Neves. et al (2005) Studied **Compressive behavior of steel fiber reinforced concrete.** They have investigated the influence of matrix strength, fiber content and diameter on the compressive behavior of steel fiber reinforced concrete was presented. Two types of matrix and fibers were tested. Concrete compressive strengths of 35 and 60 MPa, 0.38 and 0.55 mm fiber diameter, and 30 mm fiber length, were considered. The volume of fiber in the concrete was varied up to 1.5%. Test results indicated that the addition of fibers to concrete enhances its toughness and strain at peak stress, but can slightly reduce the Young's modulus. Simple expressions were proposed to estimate the Young's modulus and the strain at peak stress, from the compressive strength results, knowing fiber volume, length and diameter. An analytical model to predict the stress–strain relationship for steel fiber concrete in compression was also proposed. The model results were compared with experimental stress–strain curves.

Ganesan N. et al (2005). Studied **Permeability of Steel Fiber Reinforced High Performance Concrete Composites.** They have carried out to study the combined effect of addition of micro-silica and steel fibers on the durability of steel fiber reinforced-high performance concrete (SFR-HPC) composites. A high performance concrete of M60 grade was considered and water permeability test was conducted to find the durability of SFR-HPC composites. The main variables considered in this study are: (i) five different percentages of micro-silica, namely, 0.0,2.5, 5.0, 7.5 and 10.0; (ii) three different aspect ratios of steel fibers and (iii) three different volume fractions of steel fibers. A total of 84 numbers of concrete specimens were cast with and without micro-silica and steel fibers, and tested as per IS: 3085 specifications for permeability. Test results indicate that the addition of micro-silica to plain concrete reduces its permeability by about 63% and further addition of steel fibers to micro-silica added concrete reduces its permeability again by about 73%. Thus, an overall reduction in permeability of as high as 90% could be achieved by adding both micro-silica and steel fibers to plain concrete.

Singh S.P. et al (2006) Studied **Flexural fatigue strength of steel fibrous concrete containing mixed steel fibers.** They conducted to study the fatigue performance of steel fiber reinforced concrete (SFRC) containing fibers of mixed aspect ratio. An extensive experimental program was conducted in which 90 flexural fatigue tests were carried out at different stress levels on size 500 mm×100 mm×100 mm SFRC specimens respectively containing 1.0%, 1.5% and 2.0% volume fraction of fibers. About 36 static flexural tests were also conducted to determine the static flexural strength prior to fatigue testing. Each volume fraction of fibers incorporated corrugated mixed steel fibers of size 0.6 mm×2.0 mm×25 mm and 0.6 mm×2.0 mm×50 mm in ratio 50:50 by weight. The results were presented both as *S-N* relationships, with the maximum fatigue stress expressed as a percentage of the strength under static loading, and as relationships between actually applied fatigue stress and number of loading cycles to failure. Two-million-cycle fatigue strengths of SFRC containing different volume fractions of mixed fibers were obtained and compared with plain concrete.

Bhalchandra S.A. et al (2007), Studied **'Performance of high strength steel fiber reinforced concrete'.** They present work deals with the results of experimental investigations on high strength fiber reinforced concrete. Variable ingredients are silica fume and superplastisizer (by % weight of cement). Fiber content varied from 0 to 5% at interval of 0.5% by weight of cement in high grade mix compressive strength, flexural strength at 28 days. The maximum increase in compressive strength is up to 4.73 % at 4.5 % of fiber content .It is observed that the flexural strength increases with increase in the fiber content up to 2%. The maximum increase in this strength, i.e. 23.34 at 2.0 % fiber content over that of normal concrete.

Ganeshan N. et al (2007), in their entitled **'Steel fiber reinforced high performance concrete for seismic resistant structure'** have attempted to carry out large scale investigations on SERHPC structural elements like columns, beams and beam column joints. In this paper they have presented consolidated details of the investigations. They have used crimped steel fibers in FRC. Also they have considered 10% replacement of cement by silica fume and 20% by fly ash.

Regarding compressive behavior the authors have given following findings.

1) SFRHPC can be obtained using conventional constituents of concrete and fibers, with due care in the selection of ingredients and proportioning of the mix.
2) An increase in the volumetric ratio of transverse reinforcement increases the ultimate strength of HPC and SFRHPC. However the percentage of increase is higher for SFRHPC specimens than for HPC.
3) As the confinement increases strain at peak load increases. Addition of steel fibers improved this peak strain further.
4) The addition of short discrete randomly oriented steel fibers improves the dimensional stability of the structure to a great extent.
5) This investigation indicates that the combined effect of confinement in the form of square/rectangular/circular hoops and randomly oriented steel fibers enhances the strength and ductility of compression members such as columns to a great extent and this is the major requirement for a seismic resistant structure.

Ramadoss P. et al (2007). Studied **Toughness of steel fiber reinforced silica fume concrete under compression and Dynamic mechanical performance of high-performance fiber reinforced concrete.** They have studied the Effect of Crimped steel fibers with aspect ratio of 80 with 0%, 0.5%, 1.0% and 1.5% and silica fume of 10 % replacement by variation in w/c from 0.25 to 0.40. The compressive strength was found to be in range of 52 to 75 Mpa. The ultrasonic pulse velocity test was conducted to study the uniformity of composite including fiber distribution. From the experimental results, a statistical model has been developed, for predicting the compressive strength of high performance fiber reinforced concrete over a wide range of w/c ratios, Fiber and silica fume.

Bhalchandra S.A. et al (2007). Studied **Performance of high strength steel fiber reinforced concrete.** They present work deals with the results of experimental investigations on high strength fiber reinforced concrete. Variable ingredients are silica fume and superplastisizer (by % weight of cement). Fiber content varied from 0 to 5% at interval of 0.5% by weight of cement in high grade mix compressive strength, flexural strength at 28 days. The maximum increase in compressive strength is up to 4.73 % at 4.5 % of fiber content .It is observed that the flexural strength increases with increase in the fiber content up to 2%. The maximum increase in this strength, i.e. 23.34 at 2.0 %.fiber content over that of normal concrete.

Rakesh Kumar. et al (2007). Studied **Bond strength of steel fiber reinforced concrete.** They have carried out the bond versus slip characteristics of different reinforcing bars embedded in steel fiber reinforced concrete were determined and compared with plain cement concrete. The main reinforcing bars used in this experimentation were mild steel (MS), cold twisted deformed (CTD) and thermal mechanical treated (TMT). The fiber content was varied 1.0, 1.5 and 2.0 percent by volume of concrete. The concrete used was M25 grade.

The specimens were tested at 7 and 28 days. The results were compared with the codal values. From this study, it was observed that the addition of steel fiber increases the bond strength of reinforced concrete.

A. K. Gurav. et al (2007). Studied **Effect of addition of silica fume on the strength properties of sifcon produced from waste coiled steel fibers.** They have studied the effect of addition of silica fume on the properties of SIFCON was reported. SIFCON was made from waste coiled steel fibers obtained from lathe machine shop having aspect ratios like 80, 90, 100, 110 and 120 were used. Specimens were casted by adding silica fume at varying percentages like 5%, 10%, 15%, 20%, 25% and 30% by weight of cement. The strength characteristics like compressive strength, tensile strength, and flexural strength and impact strength are evaluated. The SIFCON produced with fibers having an aspect ratio of 120 yields the maximum strength. The optimum percentage of addition of silica fume for SIFCON was considered as 25% by weight of cement.

Ramadoss, P. et al (2007) .Studied **Behavior of high-performance fiber reinforced concrete plates.** They have studied on the behavior of high-performance fiber reinforced concrete (HPFRC) plates was carried out to evaluate the performance of plates under in-plane and lateral loads. The plates were tested in simply supported along all the four edges and subjected to in-plane and traverse loads. In this experimental program, twenty four 150mm diameter cylinders and nine plate elements of size 600x600x30 mm were cast and tested. The water-to-cementitious materials ratios of 0.3 and 0.4 with 10 % and 15 % silica fume replacements were used in the concrete mixes. The fiber volume fractions, Vf = 0%, 1% and 1.5% with an aspect ratio of 80 were used in this study. The HPFRC mixes had the concrete compressive strengths in the range of 52.5 to 70MPa, flexural strengths ranging from 6.21 to 11.08MPa and static modulus of elasticity ranging from 29.68 to 36.79GPa. Ultrasonic pulse velocity test was carried out on the cylindrical specimens for the assessment of the quality of the fiber reinforced concrete mixes. Test results indicate that the strength, failure mode, crack propagation, and load-deflection were greatly influenced by the addition of fibers in the composite slabs.

Francesco Bencardino. et al (2008). Studied **Stress-Strain Behavior of Steel Fiber-Reinforced Concrete in Compression.** They have presented the results of tests in compression of steel fiber-reinforced concrete carried out according to standard procedures, and a critical evaluation of the models proposed to define the stress-strain behavior in compression. The tests reported were carried out on cylindrical specimens of plain and steel fiber-reinforced concrete with fiber volume of 1, 1.6, and 3% and silica fume 6%. They developed the reliability of the models available in literature; a critical comparative study was carried out between the experimental data and the various proposed theoretical stress-strain relationships. It was shown that while many of the models showed good agreement with test results from which the model equations were derived, there was no such good agreement when the models were applied to other published test data. The strain at failure of SFRC exhibits a value higher than 0.0035, SFRC specimens with fiber content of 1.6 and 3% show, at 0.01 strains, a residual stress of about 74 and 78% of their respective peak stresses.

S. P. Singh. et al (2008). Studied **Flexural fatigue strength prediction of steel fiber reinforced concrete Beams.** They have investigated to study the fatigue strength of steel fiber reinforced concrete (SFRC) containing fibers of mixed aspect ratio were presented. Approximately eighty one beam specimens of size 500 mm x 100 mm x 100 mm were tested under four-point flexural fatigue loading in order to obtain the fatigue lives of SFRC at different stress levels. About thirty six static flexural tests were also carried out to determine the static flexural strength of SFRC prior to fatigue testing. The specimens incorporated 1.0, 1.5 and 2.0% volume fraction of corrugated steel fibers. Each volume fraction incorporated fibers of two different sizes i.e. 2.0 x 0.6 x 25 mm and 2.0 x 0.6 x 50 mm by weight of the longer and shorter fibers in the ratio of 50% - 50%. Fatigue life data obtained has been analyzed in an attempt to determine the relationship among stress level, number of cycles to failure and probability of failure for SFRC. It was found that this relationship can be represented reasonably well graphically by a family of curves. The experimental coefficients of the fatigue equation have been obtained from the fatigue test data to represent the curves analytically.

Mohammadi Y. et al (2008), Studied **'Properties of Steel Fibrous Concrete Containing Mixed Fibers in Fresh and Hardened State'.** They have investigated the properties of SFRC containing fibers of mixed aspect ratio such as compressive strength, splitting tensile strength, flexural strength, and flexural toughness. The sizes of the mixed steel fibers used where 0.6 × 2.0 × 25 mm and 0.6 × 2.0 × 50 mm in different proportions by weight. They reported that the maximum increase in compressive strength of SFRC (containing short fibers only) was 25% over the plain concrete at fiber volume fraction of 2.0%, an increase of 59% in splitting tensile strength of SFRC with respect to plain concrete (65% long fibers and 35% short fibers) at a fiber volume fraction of 2.0%, a maximum increase in flexural strength of SFRC of 100%, and the higher values of the flexural toughness indices were obtained at higher fiber volume fractions and at higher percentages of the longer fibers in SFRC mixes.

H. Katkhuda. et al (2009). Studied **Influence of Silica Fume on High Strength Lightweight Concrete.** Their main objective was to determine the isolated effect of silica fume on tensile, compressive and flexure strengths on high strength lightweight concrete. Many experiments were carried out by replacing cement with different percentages of silica fume at different constant water-binder ratio keeping other mix design variables constant. The silica fume was replaced by 0%, 5%,10%, 15%, 20% and 25% for a water-binder ratios ranging from 0.26to 0.42. The results showed that the tensile, compressive and flexure strengths increased with silica fume incorporation but the optimum replacement percentage was not constant because it depends on the water–cementitious material (w/cm) ratio of the mix. The optimum SF replacement percentages for obtaining maximum 28 day compressive and flexure strengths of lightweight high strength concrete ranges from 15% to 25% depending on the w/c ratio of the mix. The optimum percentage of SF replacement increases with the increase of w/c ratio. This percentage was almost a unique for tensile strength where it was noted 15% for w/c 0.26 and 0.30, and 20% for w/c 0.34, 0.38 and 0.42. Based on the results, a relationship between split tensile, compressive and flexure strengths of silica fume concrete was developed using statistical methods.

Ramli M. et al (2010), Studied **'Effect of Steel Fibers on the Engineering Performance of Concrete'.** They have investigated the effect of steel fiber content with different percentages of steel fiber from (0-2%) on the flow able mortar. The results indicated that the compressive strength has increased by 21% as the steel fiber fractions was 1.25%. On the other hand, the flexural strength results recorded a significant increase of about 200% by the inclusion of steel fiber up to 1.75%. These results according to the authors are related to the improvement of mechanical bond between the cement paste and the steel fibers when the flow of mortar is adequately applied.

D.N.Kakade. et al (2010). Studied **Performance of steel fiber and silica fume of high strength concrete.** They have investigated the combined effect of silica fume of 7.5% as constant and steel fiber content of 0.5 to 5 is varying. They studied on workability, density and compressive strength, flexural strength and shear strength on M50 grade of concrete. All the specimens are water cured and tested after 28 days. The maximum increase in compressive strength up to 19.69%, flexural strength up to 30.44% at 2.0% of fiber and 7.5% of silica fume.

Biswal K. C. et al (2011). Studied **Effect of superplastisizer and silica fume on properties of concrete.** They have studied to reduce the water/powder ratio and increase the binder content. Superplasticizers were commonly used to achieve the workability. Silica fume was one of the popular pozzolanas used in concrete to get improved properties. The use of silica fume in conjunction with superplastisizers has become the backbone of high strength and high performance concrete. An experimental program has been carried out to study the effect of superplasticizer alone and in conjunction with silica fume on some of the properties of fresh and harden of concrete. The compressive of concrete was increased by use of silica fume up to 20% replacement of cement. The flexural strength of concrete was increased by used of silica fume up to 15% replacement of cement.

II. Summary

A comprehensive review of literature covering papers from Journals and conferences was carried out; papers reviewed were predominantly based on fiber reinforced concrete. The literature review indicates that very few research and publications are available on the fiber reinforced concrete with silica fumes and variables such as aspect ratio, different grades of concretes and different percentages of steel fibers with hybrid aspect ratio are simultaneously not covered in papers reviewed. Few work is reported in the development of mathematical models and their validation using own experimental values and values from other researches, considering parameters like

Compressive strength, Split tensile strength and Flexural Strength for Steel fiber reinforced concrete.

Comparative analysis of Fiber Reinforced Concrete with Silica Fumes								
Sr no	Reference No.	Types of Fiber	Silica Fumes	Fly Ash	Hybrid Aspect Ratio Fibers	Tensile Strength	Compressive Strength	Flexural Strength
1	1	Steel	✔	-	-	-	✔	✔
2	2	Steel	-	-	-	-	-	-
3	3	Steel	-	-	-	-	-	-
4	4 – 7	Steel	-	-	-	-	-	✔
5	5	Steel	✔	✔	-	-	✔	✔
6	6-16-17-34	Steel	-	-	-	-	✔	✔
7	08-09-20-13	Steel	-	-	-	-	✔	-
8	10	-	✔	-	-	-	-	-
9	11	Steel	-	-	-	-	✔	-
10	12	-	✔	-	-	✔	✔	-
11	14-22-31	Steel	-	-	-	-	-	✔
12	15-32	Steel	✔	-	-	✔	✔	✔
21	18	Steel	-	-	-	✔	✔	✔
13	19-21-30	Steel	✔	-	-	-	-	-

14	23	Steel	✔	-	-	-	✔	✔
15	24	Steel	✔	✔	-	-	-	-
16	25	Steel	✔	-	-	-	✔	-
17	26	Steel	✔	-	-	-	✔	✔
18	27	Steel	-	-	-	-	-	-
19	28	Steel	✔	-	-	✔	✔	✔
20	29	Steel	✔	-	-	-	✔	✔
22	33	-	✔	-	-	✔	✔	✔
23	35	Steel	✔	-	-	-	✔	✔
24	36	-	✔	-	-	-	✔	-

References

[1]. Balaguru P. and Kendzulak J., 1986, 'Flexural behavior of slurry infiltrated fiber concrete (SIFCON) made using condensed silica fume', ACI special publication , Vol 91, pp 1215-1230

[2]. Govindan P., Lakshmipathy M., and Santhakumar A. R., 1986, ACI JOURNAL, Proceedings, Vol 83, No 4, pp 567-576

[3]. Srinivasalu et al, 1987, Examined that the dynamic behaviour of reinforced concrete beams with equal tension and compression reinforced and varying percentages of steel fibers was studied at SERC, ACI Special publication, Vol 105, pp 283-304.

[4]. Ramakrishnan V, Wu G.Y. and Hosalli G, 1989. Flexural behaviour and toughness of fiber reinforced" Transportation Research Record, No.1226, pp 69-77

[5]. Bayasi, Z Soroushian, P, "Optimum use of Pozzolanic materials in steel fiber reinforced concrete" Transportation Research Board, 1989, pp25-30.

[6]. Soroushian P. and Bayasi Z., 1991, Fiber-type effect on the performance of steel fiber reinforced concrete, ACI Materials Journal , Vol 88, No 2, pp 129-134

[7]. Soroushian P. and Tlili A. 1991, 'Latex modification effects on the impact resistance and toughness of plain and steel fiber reinforced concrete', Transportation Research Record, No 1301, pp 6-11

[8]. Sustersic J., Mali E. and Urbancic S. 1991, 'Erosion-abrasion resistance of steel fiber reinforced concrete', SP126-39 :Special Publication, Vol 126, pp 729-744

[9]. Lin Showmay Hsu and ChengTzu Thomas Hsu Stress-Strain Behavior of Steel-fiber High- Strength Concrete under Compression Structural Journal Vol.91, No.4-July1994, pp.448-457

[10]. Khedr Safwan A. and Mohamed Nagib Abou-Zeid, "Characteristics of Silica-Fume Concrete" Journal of materials in civil engineering (ASCE) Vol.6, Issue 3- August1994, pp357-375.

[11]. Kuruvilla J., Romildo Dias Tolêdo Filho, Beena James, Sabu Thomas & Laura Hecker de Carvalho, 1999, A review on sisal fiber reinforced polymer composites, R. Bras. Eng. Agríc. Ambiental, Campina Grande, Vol III, No III, pp 367-379

[12]. Nataraja, M.C. Dhang, N. and Gupta, A.P., "Stress-strain curve for steel fiber reinforced concrete in compression", Cement and Concrete Composites, 21(5/6), (1999), pp 383- 390.

[13]. Yoon-Keun Kwak,Marc O.Eberhard,Woo-Suk Kim, and Jubum Kim, "Shear Strength of Steel Fiber-Reinforced Concrete Beams without Stirrups",ACI Structural Journal / July-August 2002,pp.530-538.

[14]. Damgir R.M. and Ishaque M.I., 2003, Effect of silica fume and steel fiber composite on strength properties of high performance concrete, Proceeding of the INCONTEST 2003, Coimbatore, pp281-286

[15]. Ghugal, Y. M., "Effects of Steel Fibers on Various Strengths of Concrete," Indian Concrete Institute Journal, Vol. 4, No. 3, (2003), pp. 23-29.

[16]. Ghavami K., Rodrigues C. & Paciornik S., 2003, "Bamboo: Functionally Graded Composite Material", Asian Journal of Civil Engineering (building & housing), Vol. 4. pp 1-10

[17]. Yu-Cheng Kan., Kuang-Chih Pei and Hsuan-Chih Yang, "An Investigation on Toughness of Steel Fiber Reinforced Heavy Concrete", Transactions of the 17th International Conference on Structural Mechanics in Reactor Technology (SMiRT 17) Prague, Czech Republic, August 17 –22, 2003,pp.1-6.

[18]. Padmanaban I. & Kandasamy S., 2004, Experimental Studies on High Performance Concrete: A State-of-Art Review, Proceedings of ICFRC, Vol I, pp 849-8

[19]. Song P.S. and Hwang S.," Mechanical properties of high-strength steel fiber- reinforced concrete "Construction and Building Materials, 2004,pp669-676.

[20]. Yin-Wen Chan and Shu-Hsien Chu,**"**Effect of silica fume on steel fiber bond characteristics in reactive powder concrete ",Cement Concrete Research ,Vol.34,Issue 7,July 2004,pp1167-1172.

[21]. Neves. R. D. and J. C. O. Fernandes de Almeida, "Compressive behaviour of steel fiber reinforced concrete", Structural Concrete -2005, Vol.6, pp.1-8.

[22]. Ganesan N. and Sekar T., 2006, 'Effect of micro-silica and steel fibers on the strength of high performance', Journal of structural engineering, India (SERC), Vol 33, No 3, pp 225-229

[23]. Singh S.P, Mohammadi Y. and Madan S.K., "Flexural fatigue strength of steel fibrous concrete containing mixed steel fibers",Journal of Zhejiang University science a, 2006 7(8) pp:1329-1335.http://www.zju.edu.cn/jzus.

[24]. Ganeshan N et al, 2007, 'Steel fiber reinforced high performance concrete for seismic resistant structure', Civil Engineering and Construction Review, pp 54-63

[25]. P.Ramadoss, V.Prabakaran, K.Nagamani, "Dynamic mechanical performance of high-performance fiber reinforced concrete" International Conference on Recent Developments in Structural Engineering (RDSE-2007),pp 1037-1046 , Manipal, India.

[26]. Bhalchandra S.A. and Ghugal Y.M. 2007, Performance of high strength steel fiber reinforced concrete, International Conference on Recent Developments in Structural Engineering , pp 1019-1025.

[27]. Rakesh Kumar, P.K.Mehta and Madhusudan P. "Bond strength of steel fiber reinforced concrete", International Conference on Recent Developments in Structural Engineering (RDSE-2007), pp740- 747, Manipal Institute of Technology, Manipal-India.

[28]. Gurav A. K. and K. B. Prakash, "Effect of addition of silica fume on the strength properties of sifcon produced from waste coiled steel fibers", International Conference on Recent Developments in Structural Engineering (RDSE-2007),pp 922-933,Manipal Institute of Technology, Manipal-India.

[29]. Ramadoss P.,Nagamani K. and Thirunavukarasu.G, "Behavior of high-performance fiber reinforced concrete plates" International Conference on Recent Developments in Structural Engineering (RDSE-2007),pp 1026-1036, Manipal Institute of Technology, Manipal-India.
[30]. Francesco Bencardino; Lidia Rizzuti; Giuseppe Spadea; and Ramnath N. Swamy, "Stress-Strain Behavior of Steel Fiber-Reinforced Concrete in Compression," Journal of materials in civil engineering (ASCE) March2008, pp.255-263.
[31]. S. P. Singh & B. R. Ambedkar, Y. Mohammadi and S. K Kaushik, "Flexural fatigue strength prediction of steel fiber reinforced concrete Beams", Electronic Journal of Structural Engineering (8) 2008, pp.46-54.
[32]. Mohammadi Y, Singh SP and Kaushik SK, 2008, Properties of Steel Faibrous Concrete Containing Mixed Fibers in Fresh and Hardened State, Construction and Building Materials, Vol 22(5), pp 956-965
[33]. Katkhuda H, B. Hanayneh and N. Shatarat, Influence of Silica Fume on High Strength Lightweight Concrete", World Academy of Science, Engineering and Technology 58 -2009 pp.781-788.
[34]. Ramli M. and E.T. Dawood, 2010, Effect of Steel Fibers on the Engineering Performance of Concrete", Asian J. Applied Sci., Vol.4, pp 97-100
[35]. Kakade D.N., Ghugal Y.M., 2010, Performance of Steel Fiber and Silica Fume on High Strength Concrete, International conference on Innovation, Vol I, pp 463-470
[36]. Biswal K. C. and Suresh Chandra Sadangi, "Effect of superplasticizer and silica fume on properties of concrete", ACEE, Conference, March 2011.