Experimental Study of Use of Steel Fiber and Silica-Fume in High Strength Concrete.

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Abstract: **Steel Fiber is found to be the most suitable for increasing strength of concrete mix. Using Steel Fiber would increase some cost but it gives return many times of its cost as a increasing of Compressive strength, Split Tensile Strength, Flexural Strength and as well as provide better stability against Earthquake as the need for greater importance as a drawn-out arrangement in the Indian concrete industry. In the present analysis, we have added steel fiber i.e. 0.5 % to 2.0 % of cement content in concrete mix for gettingbetter test results. The focus of this research is to Increase strength of concrete mix in various manner for getting high heights in construction industry. This study examines the effect of using steel fiber with silica fume in High Strength Concrete Mix i.e. M 60. Total 270 concrete specimens were cast in this study. The specimens were prepared for the concrete mix of M 60 grade using w/c ratio 0.32. The effects on different properties of concrete with Steel Fiber added concrete mix were evaluated in this study. The specimens of concrete mixes were tested for compressive strength, flexural strength, split tensile strength and carbonation test. Test results of the samples show that the strength of concrete mix increases with the use of Steel Fiber added concrete mix as 0.5 % to 2 % of cement content in M 60 Design Concrete mix. It is alsofound that carbonation depth for Steel Fiber added concrete mix concrete mix is few more as compared to Normal OPC M60 Design concrete mix. The overall results of this study show that Steel Fiber added concrete performs well in various strength tests with some modification in the mix design.**

I. INTRODUCTION

Recent earthquakes in different parts of the world have revealed again the importance of design of reinforced concrete structures with high ductility. Strength and ductility of structures depend mainly on proper detailing of the reinforcement. To avoid congestion of reinforcement and to increase flexural strength steel fibre reinforcements most suitable. However, to understandthese properties, the need for estimating the fiber contribution and the prediction of the composite's behavior is necessitated. Concrete is the most widely usedand versatile building material which is generally used toresist compressive forces.

Metakaolin, or heattreated clay, may be used as a Supplementary Cementitious Material (SCM) in concrete to reduce cement consumption, to increase strength and the rate of strength gain, to decrease permeability, and to improve durability. Metakaolin reduces the porosity of concrete. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to the concrete would act as crack resistance and would substantially improve its compressive and flexural strength properties. This type of concrete is known as fiber reinforced concrete. Fiber reinforced concrete can be defined ascomposite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformlydispersed suitable fibers. The main objective of this studyis to investigate the mechanical properties of steel fibre reinforced concrete with metakaolin. Suitability and the reliability of the destructive tests for the estimation of steel fibre reinforced concrete strength. The long process of inventing modern steel fiber reinforced concrete started in 1874, when A. Bernard, in California, patented the idea of strengthening concrete with the help of the addition of steel splinters (Maidl 1995). Another 36 years passed before Porter in 1910 mentioned the possibility of applying short wire to concrete. This was supposed to improve homogeneity of concrete reinforced by thick wire. In 1918, in France, H. Alfsen patented a method of modifying concrete by long steel fibers, long wooden fibers, and fibers made of other materials. According to him, the addition of such fibers was to increase tensile strength of concrete (Maidl 1995). Alfsen was the first tomention the influence of coarseness of the surface of fibers onto their adhesiveness to matrix, and it was also hewho paid special attention to the problem of anchorage of fibers. After these first patents, there were numerous others, but generally they concerned different shapes and probable applications of ready made SFRC. For instance,the patent from 1927 worked out in California by G.C. Martin, regarded the production of SFRC pipes. In 1938,

N. Zitkewic patented a way to increase the strength and impact resistance of concrete by adding cut pieces of steelwire (Jamrozy 1985). Steel fibers, patented in 1943 by G. Constancinesco, were already very similar to the ones used at present. The patent, apart from different shapes of fibers, contained information about the kind and dispersion of cracks during loading of SFRC elements andit made mentioned of the great amount of energy which is absorbed by SFRC under impact. The largest number of patents concerning the use of steel fibers to modify concrete have been submitted in the USA, France, and Germany in the years following. Wide applications of fiber reinforced composites in civil engineering were limited for a long time by lack of reliable methods of examination and mainly by the sudden progress of traditional rod reinforcement.

II. LITERATURE REVIEW

The latest review of literature for the proposed study has been collected in the following headlines.

Mansur *et al.* (1985) proposed empirical equations and also developed analytical models for the torsional strength of fiber reinforced concrete beams in pure torsion. Very little research work was reported on plain concrete rectangular beams and rectangular beams without web reinforcement under bending, shear and torsion. Many researchers carried out tests on reinforced concrete beams with longitudinal reinforcement and web reinforcement under bending, shear and torsion and proposed modes of failure and some empirical formulae. Comparatively fewer attempts were carried out on fiber reinforced concrete beams in bending, shear and torsion. They carried out the tests on steel fiber reinforced concrete beams (without longitudinal and web reinforcement) in combined bending and torsion and in combined bending, shear and torsion respectively. They proposed two modes of failure as Mode 1 and Mode 2. They proposed two equations to predict the torsional strength of steel fiber reinforced concrete beams.

Toutanji *et al.* (1996) documented a test where 16 and 25% of cement used in the paste and mortar, measured by mass, was replaced by SF. Four different water/cement (w/c) ratio mixes were tested: 0.22, 0.25, 0.28 and 0.31 with the proper addition of super plasticizer amount. Their results showed that the partial replacement of cement by SF increased the compressive strength of mortar, but had no effect on the compressive strength of the paste.

Langan *et al.* (2002) investigated the following conclusions:-

(1) Substantial increase in compressive strength of concrete.
(2) Reduction in the required cement content for specific target strength (saving of cement and reducing the cost of concrete).
(3) Durability increase for hardened concrete when added in optimum amounts.

Malaikah *et al.* (2003) investigated the properties of HSC with w/c ratios ranging between 0.20 and 0.35 as well as with an increase of SF according to the following percentages: 0, 10 and 15%, respectively. The results showed that the highest strength resulted from the addition of 10% SF with 0.20 w/c ratio, which resulted in a strength exceeding 100 MPa. Mazloom et al. (2003) studied experimentally the short and long term mechanical properties of high-strength concrete containing different levels of SF. As the proportion of SF increased, the workability of concrete decreased. However, short-term mechanical properties such as the 28-day compressive strength and secant modulus improved.

Shakir *et al.* (2005) studied the effect of steel fibers on the mechanical properties of high performance concrete studied the effect of steel fibers content and the combined effect of rice husk ash (RHA) and high range water reducing agent (HRWRA) on the mechanical properties of the produced matrix. The experimental results showed the using steel fibers in High-performance concrete led to a considerable improvement in mechanical properties of concrete. The results exhibited that the addition of steel fibers to high performance concrete up to 1% with 6% (HRWRA) and 8% (RHA) as a partial replacement by weight of cement, increases the compressive strength significantly. Also, the results showed that the addition of 1.5% steel fibers with 6% (HRWRA) and 8% (RHA) increases the splitting and flexural strengths significant. At 28 days, the compressive, splitting and flexural strengths were increased to 11.57%, 63.86%, and 32.93% more than High performance concrete without steel fibers, respectively.

Gonen *et al.* (2007) stated that SF contributed to both short and long-term properties of concrete, whereas FA shows its beneficial effect in a relatively longer time. As far as the compressive strength is concerned, adding of both SF and FA slightly increased compressive strength, but contributed more to the improvement of transport properties of concrete. Sata et al. (2007) showed that by replacing 10% SF, and 10, 20, 30 and 40% of FA instead of Portland cement with a constant w/c ratio of 0.28, FA increased the strength after 28 days in which the highest strength gained was by replacing 20% of FA.

Banthia *et al.* (2007) stated that the crimped steel fibers with large diameters are often used in concrete as reinforcement. Such large diameter fibers are inexpensive, disperse easily and do not unduly reduce the workability of concrete. However, due to their large diameters, such fibers also tend to be inefficient and the toughness of the resulting fiber reinforced concrete (FRC) tends to be low. Hence, an experimental program was carried out to investigate if the toughness of FRC with large diameter crimped fibers can be enhanced by hybridization with smaller diameter crimped fibers while maintaining workability, fiber dispersability and low cost. The results showed that such hybridization, replacing a portion of the large diameter crimped fibers with smaller diameter crimped fibers can significantly enhance toughness. The results also suggested that such hybrid FRC, fail to reach the toughness levels demonstrated by the smaller diameter fibers alone.

Lin *et al.* (2008) studied effect of steel fiber on the mechanical properties of cement based composites containing silica fume. It carried out to evaluate the mechanical properties of cement based composites. Test variables included water to cementitious ratio, dosage of silica fume and volume fraction of steel fiber. Compressive strength test, direct tensile strength test, splitting tensile strength test, abrasion resistance test and drop weight test were performed and the results were analyzed statistically. According to the results of this study, the designed direct tensile testing method was a suitable method to estimate the tensile strength of fiber cement- based composites. Addition of fibers provided better performance for the cement-based composites, while silica fume in the composites would help obtaining uniform fiber dispersion in the matrix and improve strength and the bonding between fiber and matrix resulting from extra dense calcium-silicate-hydrate gel. The combination of steel fibers and silica fume can greatly increase the mechanical properties of cement-based composites. Besides, a multiple regression analysis was conducted to correlate compressive strength, direct tensile strength, abrasion coefficient and impact number with w/cm ratio, silica fume content and steel fiber content and a fairly agreement between test data and estimated values was found.

Katkhuda *et al.* (2009) studied the effects of silica fume on tensile, compressive and flexure strengths on high strength lightweight concrete. It 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 0.26 to 0.42. For all mixes, split tensile, compressive and flexure strengths were determined at 28 days. The results showed that the tensile, compressive and flexure strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the watercementitious material (w/cm) ratio of the mix. Based on the results, a relationship between split tensile, compressive and flexure strengths of silica fume concrete was developed using statistical methods.

Pawade Prashant *et al.* (2011) studied the influence of Silica fume in enhancement of compressive strength, flexural strength of steel fibers concrete and their relationship. They investigated on concrete due to the effect of silica fume with and without steel fibers on Portland Pozzolona cement. In this study we used concrete mixes with Silica Fume of 0%, 4%, 8% and 12% with addition of crimped steel fibers of two diameters 0.5mm Ø and 1.0 mm Ø with a constant aspect ratio of 60, atvarious percentages as 0%, 0.5 %, 1.0 % and 1.5 % by the volume of concrete on M30 grade of concrete. In comparison, with control concrete the replacement of 4%,8%, 12% and 16% cement by silica fume showed 7.46%,

11.17%, 11.91% and 9.83% increase in compressive strength at 28 days of curing. The optimum combined effect at 8% silica fume and 1.5% steel fiber with normal concrete the maximum compressive strength increase at mm Ø and 1.0 mm Ø steel fiber at 28 days of curing were 15.38% and 18.69%, the maximum flexural strength increase were 17.13% and 24.02%. The combined effect of silica fume at 4% & 12% with steel fiber at 0.5%, 1.0% & 1.5% of both diameters 0.5 mm Ø and 1.0 mm Ø at different ages of curing are presented.

Pilegis *et al.* (2016) presented a laboratory study in which manufactured sand produced in an industry sized crushing plant was characterized with respect to its physical and mineralogical properties. The influence of these characteristics on concrete workability and strength, when manufactured sand completely replaced natural sand in concrete, was investigated and modeled using artificial neural networks (ANN). The results showed that the manufactured sand concrete made in this study generally requires a higher water/cement (w/c) ratio for workability equal to that of natural sand concrete due to the higher angularity of the manufactured sand particles. Water reducing admixtures can be used to compensate for this if the manufactured sand does not contain clay particles. At the same w/c ratio, the compressive and flexural strength of manufactured sand concrete exceeds that of natural sand concrete.

Zhao e*t al.* (2017) presented 755 groups splitting tensile strength tests data of concrete with manufactured sand (MSC) in different curing age ranged from 1 day to 388 days. Raw materials of MSC were the ordinary silicate cements, the admixture consisted of fly ash, slag and silicafume, the crushed stone and the manufactured sand. The cement compressive strength and tensile strength at 28 days ranged in 35.5–63.4 MPa and 6.9–10.8 MPa, respectively. The maximum grain size of crushed stone ranged from 12mm to 120mm. The fineness modulus of manufactured sand was 2.2–3.55. As these studies were done based on different codes, different maximum particle sizes of 0.075 mm and 0.160 mm were defined forstone powder in manufactured sand. The contents of stone powder with particle size of 0–0.075 mm ranged in 0–21.8%, where as those with particle size of 0-0.160 mm varied in 0-40%. The water-binder ratio W/B = 0.24–1.00, while the water-cement ratio m_W/mc = 0.30-1.43. The sand ratio was 24–54%. The compressive strength of MSC at 28 days ranged from 10.1–96.3 MPa, the slump of fresh MSC varied from 10 mm to 260 mm, the curing time of specimens ranged from 1 day to 388 days.

Kumars and Kotian (2018) compared the compressive strengths of River Sand and M-Sand was done with the hundred percent replacement of river sand and M sand. The results showed that the M Sand offers same property of River Sand. The various Tests like specific Gravity, Compression Strength test, Flexure Test, spilt tensile strength test also given the same or greater value than River sand.

Chouhan *et al.* (2019) aimed at exploring the ways to effectively utilize the stone slurry as a substitution of conventional construction and building material. They examined the mechanical and durability properties of mortar. A plethora of laboratory tests like compressive test, flexural strength, tensile test, workability test, durability test and water absorption test were conducted on the specimens. The replacement ratio undertaken was (10%, 15%, 20% and 25%). They observed that compressive and flexural strength of mortar increased with the inclusion of stone waste slurry thereby, giving an indication that stone slurry can effectively be used in concrete as a replacement of cement.

Thivya and Aarthi (2019) determined the concrete’s strength and durability by using M-Sand and Quarry Dust as sand and comparing with the conventional mix. Wide range of 28 days of healing was considered the design mix in the study of M40 grade concrete with fully replacement of M-Sand and Quarry Dust respectively have been considering for investigation. The compressive strength (cube), split tensile strength (cylinder) and flexure strength (beam) testing of concrete. The following conclusions have been investigated.

(1) The fine aggregate replacement with M-Sand and

Quarry Sand was more cost economical.

(2) The compressive strength of 28 days for M40 concrete mix with 100% River sand replacement by M-sand yield compressive strength of 63.56 N/mm².

(3) 100% replacement was reasonable where there was low workability requirement. And where there was high workability requirement, partial replacement can be made keeping in view the strength and economy.

(4) For big projects like highways, establishing a plant leads to economy as they require large amount of fine aggregate.

Zhao *et al.* (2021) investigated the effect of partial replacement of cement with high volume GGBS on the mechanical properties and workability of the concrete mix. For carrying out the evaluation, concrete cubes were cast with OPC, and various percentages of GGBS (50%, 60% and 65%). Based on the test results it was concluded that the addition of GGBS in the concrete enhances the mechanical and workability of the mix.

III. MATERIALS USED AND THEIRPROPERTIES

In this present investigation materials used are Cement, Fine aggregate (Natural Sand**)**, Coarse aggregate, Steel Fiber, Silica Fume, SuperPlasticizer, Water etc.

3.1 Martials with their Properties

3.1.1 Cement

The ordinary Portland cement (Shree cement) of 43- grade accessible in neighborhood market was utilized for projecting the specimens of all the concrete mixes. Cement was purchased from a similar source all through the experimental work. The cement was of uniform dark tone. The cement is tried on various properties according to IS: 4031-1988 and is discovered affirmation to various determinations according to IS: 12269-1987.

Table 1 Physical properties of Cement

S. No.	Physicalproperty	Requirement asper IS (4031-1988)	Test results
1	Consistency	26-33%	33%
2	Initial setting time Final setting time	30 minutes (min.) 600 minutes (max.)	118 minutes 311minutes
3	Specific gravity	3.12-3.19	3.11

3.1.2 Fine Aggregate

Fine aggregates would be sieved to remove particles larger than 4.75 mm. The locally available river sand passing 4.75 mm sieve as per IS: 383-2016 will be used as fine aggregate for this investigation.

It should be free from organic matter, loam, silt, salt and clay. It should be hard, strong and durable as in Fig. 3.1. It stiffens the binder and fills the voids in thecoarse aggregate.

River sand with a specific gravity of 2.67 and fineness modulus of 2.83 was used as fine aggregate.

Figure 2 Fine aggregate

3.1.3 Coarse Aggregates

The aggregate which goes through 80 mm sieve and is held on 4.75 mm sieve, is known as coarse aggregate. The 10 mm and 20 mm size of coarse aggregate were used in this study. The coarse aggregate used for investigation was purchased from the local coarse aggregate supplier as per BIS: 383- 1970. Coarse aggregate should be free from dust particles, vegetation, organic matters, and clay as in Fig. 3.2. It should be rakish fit as a fiddle which shows great interlocking properties. Water utilized for mixing and healing will be clean and free from harmful volumes of oils, acids, alkalis, salts, organic materials or other materials. Versatile water will be utilized for blending just as curing of concrete as prescribed in IS: 456-2000. Crushed granite of specific gravity of 2.63 was used as coarse aggregate. Two different classes of coarse aggregate fractions were used: 10-4.75 mm and 20-10 mm.

Figure 3 Coarse aggregate

3.1.4 Water

The nature of the water plays a significant role in production of concrete. The impurities in water may affect the setting of the cement and the final strength of the concrete or cause staining of its surface, and may also lead to corrosion of the reinforcement. Water utilized for mixing and healing was clean and free from harmful materials. Water was taken from the same source throughout the investigation. Water utilized for mixing and healing will be clean and free from harmful volumes of oils, acids, alkalis, salts, organic materials or other materials. Versatile water will be utilized for blending just as curing of concrete as prescribed in IS: 456-2000. Ordinary tap water available in the laboratory and used for drinking purposes was used for mixing of concrete.

3.1.5 Admixture

Sika Viscocrete - 713 PR was used to increase the workability of freshly prepared fiber reinforced concrete.

Figure 4 Sika Viscocrete - 713 PR (SuperPlasticizer)

3.1.6 Steel fibers

Crimped Steel fibres of 12 mm length and 0.5mm diameter with aspect ratio-24 manufactured by Bajaj Reinforcements Conforming to IS 13320: 2013 were used in this study. The main variables used in the study are Round Crimped Steel Fiber (RCSF) with different dosages of fibers was used by weight of volume of concrete.

Different Types of Fibers

Following are the different type of fibers generally used in the construction industries.

3.1.6.1 Steel Fiber
3.1.6.2 Polypropylene Fiber
3.1.6.3 Glass Fiber
3.1.6.4 Asbestos Fibers
3.1.6.5 Carbon Fibers
3.1.6.6 Organic Fibers.

3.1.6.1 Steel Fiber

A number of steel fiber types are available as reinforcement. Round steel fiber the commonly used type is produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick. Fiber made from mild steel drawn wire.

Figure 5 Steel Fibers.

Reference: Properties of Fiber Reinforced High Performance Concrete-A Case Study. By C. Priyaand Dr. S. Sudalaimani.

Conforming to IS: 280-1976 with the diameter of wire varying from 0.3 to 0.5mm have beenpractically used in India. Round steel fibers are produced by cutting or chopping the wire, flat sheetfibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets. Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available. Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.

Figure 6 Steel Fibers (Actual Photo in Concrete Lab).

Figure 7 End Hook Steel Fibre. (Actual Photo inConcrete Lab.).

Figure 8 Original Photos of Steel Fiber in Lab.

Figure 9 Original Photos of Steel Fiber in Lab.

Manufacturing of Steel Fiber

Steel fibers were commercially brought into the European market in the1980's. In the beginning, no standards & recommendations were available to accept this new technology. But now,standards & recommendations are available in American & British standards. ASTM A-820 is the standard specification for steel fibers used as reinforcementin concrete.

Table 2 Components of Steel Fiber for Manufacturing it.

Carbon	0.06/0.12%
Manganese	0.38/0.60%
Phosphorus	0.055/0.065%
Sulphur	0.035%
Nitrogen	0.008/0.12%

Their manufacturing is done with special type of arrangements. Steel strips are forced into small pieces of steel fibers by introducing large energy. They are produced by two type of failure of steel strips due to energy:

- *Brittle failure*
- *Shear failure*

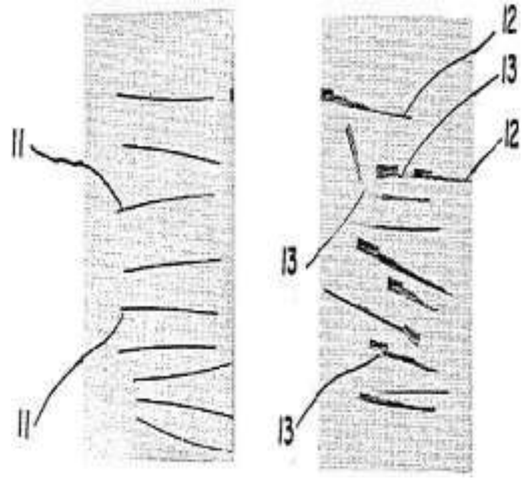

Figure 10 Various Types of Failure in Steel Fiber.

As it is clear from these words that, brittle fracture which occurs at a low-energy impact level with a minimum of plastic deformation so as to produce a straight fiber of uniform cross section, While distinguish this type of fracture from shear fracture which is associated with higher energy absorption than brittle fracture, so as to form steel fibers highly irregular in cross section. Usually the irregular cross sectioned steel fibers are considered more effective than the straight one's.

Steel Fiber Reinforced Concrete Design Consideration

Steel fibers are usually poured into the concrete at the stage of mixing cement, coarse aggregate and fine aggregates. Firstly the cement, fine and coarse aggregates are poured into the mixer after that, steel fibers are used to be poured then water is poured after that this whole assembly is mixed either by hand or by using mechanicalequipment.

Their effectiveness can be determined by using following parameters:

1. *Length*
2. *Diameter*
3. *Aspect ratio (diameter to length ratio)*
4. *Configuration*

Steel fibers are usually available in length from 1" to 2". The 1" length provides enhancement in both micro-macro cracking performance and post-first-crack performance of concrete. Aspect ratio gives better understanding of bonding potentials. Fibers having aspect ratio greater than 2" usually having balling potential. Configuration can be straight, continuous-deformed, or end-deformed. Initially, straight steel fibers were the only available. It was quickly learned that their bonding potential was limited. New products were developed to increase the bond between the fiber and concrete. As a result of which, two configurations emerged as the best one, named as *hooked-end, drawn-wire fiber **&** continuously-deformed, slit-sheet steel fiber.*

The continuous-deformed, slit-sheet fibers provide better micro-macro cracking performance, as well as flexural strength enhancement whereas, the end-deformed, drawn-wire steel fibers perform best post-first-crack. As whenever the steel fibers are used in concrete, the problem arises of workability of concrete. Steel fibers usually lowers workability of concrete. Mix becomes harsh. Despite increasing water cement ratio, as it tend to decrease strength of concrete, usually the admixtures are used.

The main objective in designing a structural fiber concrete mix is to produce adequate workability, ease of placing and efficient use of fibers as crack controllers. The ACI committee has given the following guidelines to serve the purpose of Steel fiber reinforced concrete (SFRC) mix design:

1. Coarse aggregates should be 55% of the total aggregate.
2. W/C should be below 0.55 (0.35 is recommended).
3. Minimum cement content of 320 kg/m^3 should be used.
4. Sand content of 750-850 kg/m^3 is recommended.
5. The workability could be improved by increasing the cement paste, which is possible by addition of slag or fly ash to replace the cement.
6. Maximum aggregate size should be 19 mm.

Uses of Steel Fiber

Typical applications for steel fiber concrete flooring can be found on parking lots, playgrounds, airport runways, taxiways, maintenance hangars, access roads, and workshops. This method is also widely used for port pavements, container storage and handling areas, bulk storage warehouses, and military warehouses. Steel fiber reinforced concrete is commonly used in tunnel construction, as it provides additional flexural strength, reduces shrinkage cracking and reduces permeability.

3.1.7 Silica Fume

Silica fume (SF) is a by-product of the smelting process (reduction of high-purity quartz with coal in electric furnaces) in the production of silicon and ferrosilicon alloys. It is also collected as a by-product in the production of other silicon alloys such as ferromanganese, ferromagnesium, ferro-chromium, and calcium silicon (ACI 226-3R-87). It contains extremely fine amorphous particles of silicon dioxide (SiO_2) which usually make up more than 90% of SF constituents. SF is also known as microsilica, volatized silica, and condensed SF or silica dust. SF, because of its extreme fineness and high silica content, has been recognized as a pozzolanic material conforming to specifications of ASTM C1240 for use as supplementary cementitious material in cement mortar and concrete to enhance mechanical and durability properties. According to the Florida Department of Transportation, the quantity of SF should be between 7% and 9% by mass of cement replacement for mortar and concrete production (Panjehpour et al., 2011). The use of SF is well established in concrete industries throughout the world and, perhaps, represents the most deeply entrenched and accepted use of industrial by-products in the construction industry. (R. Siddique, Kunal, in Nonconventional and Vernacular Construction Materials, 2016).

In Short, Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Silicon metal and alloys are produced in electric furnaces. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most important use of this material is as a mineral admixture in concrete.

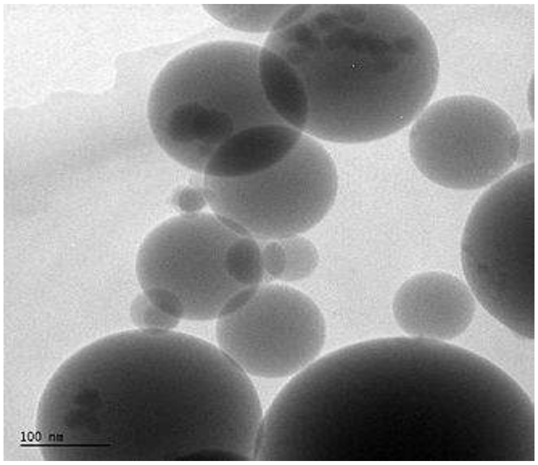

Figure 11 Silica Fume particles viewed in a transmission electron microscope i.e. Internal structure of Silica Fume. (Source: Wikipedia).

Figure 12 Pure Fine 99.99 % Silica Fume. (Actual Photo in Lab).

IV. EFFECT OF STEEL FIBER AND SILICA FUME ON THE HIGH STRENGTH CONCRETE.

4.1. Experimental program

The experimental program was intended to look at the mechanical properties i.e. compressive strength, split tensile strength, and flexural strength of concrete with M60.

4.2. Mix Proportions:

Concrete mixes were designed to a compressive strength of M 60 grades with a water-cement ratio (W/C) of 0.32 respectively as per IS code 10262-2019.

Table 1: Properties of Steel Fiber**.**

S. No	Materials	Quantities in Kg/m3
		M 60
1	Cement	508.25
2	Water	141
3	Fine aggregate	589
4	Coarse aggregate	1219
5	Water cement ratio	0.32
6	Superplasticizer	2.67
7	Steel Fiber	2.54
8	Silica Fume	2.54

The Samples of standard cubes (100 mm x 100 mm x 100 mm) standard cylinders of (150mm Día x 300mm height) and standard beams of (100mm x 100mm x 500mm) were cast.

4.3. Mechanical Properties:

4.3.1 Compressive Strength:

The compressive strength M 60 grade concrete, different Proportion of steel fibers in concrete mix at 7 and 28 days is introduced in following figures. The test was done adjusting to IS 516-1959 to get the compressive strength of concrete at 7 days and 28 days. The cubes were tested in a compression testing machine (CTM). In this study, Steel Fiber added various concrete speciemens is compared with normal opc cement speciemens ofrespective 7 and 28 days. Speciemens of steel fiber added concrete mixes with different proportions of steel fibers and there results are described in following points. The compressive strength of concrete containing steel fiber as added for increasing strength in concrete mix for M 60 grade respectively at 7 and 28 days curing is shown in Fig. It can be seen by that the compressive strength of the concrete increases with increasing curing age. The compressive strength is up to 41.97 Mpa (For OPC only at 7 days), 45.5111 MPa (For OPC with Steel Fiber at 7 days) and 60.27 Mpa (For OPC only at 28 days), 62.75 MPa (For OPC with Steel Fiber at 28 days) respectively. The compressive strength is increased by 8.44 % for M 60 grade with adding of 0.5 % steel fiber (based on cement content) at 7 days. The compressive strength is increased by 4.12 % for M 60 grade with adding of 0.5 % steel fiber (based on cement content) at 28 days.

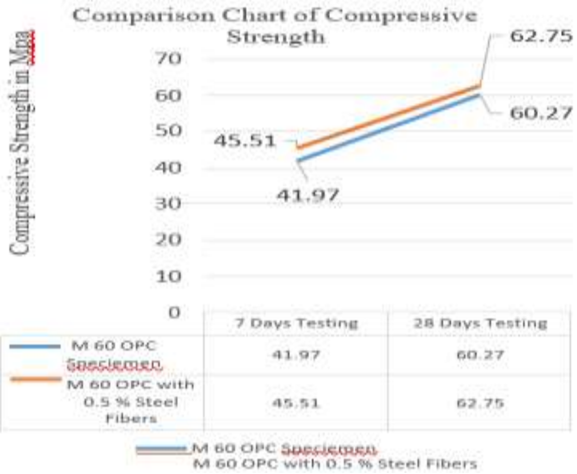

Figure 14 Comparison Chart of Compressive strength of OPC Concrete Mix and OPC Concrete Mix with Steel Fiber at 7 and 28 days. (Line Chart).

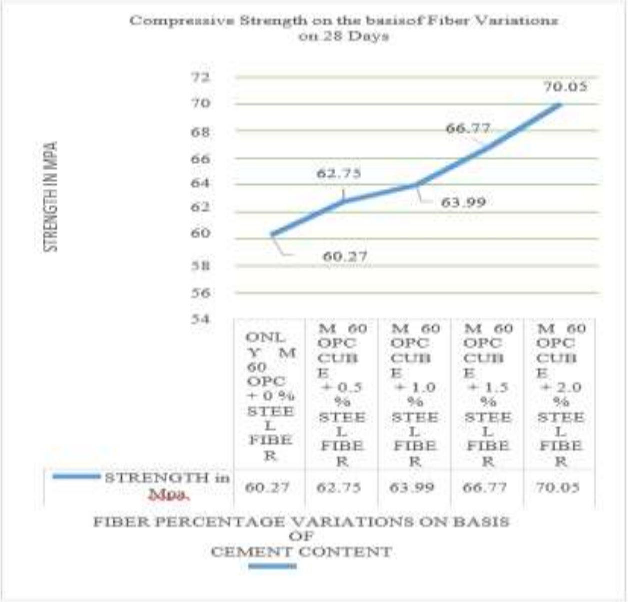

Figure 15 Line Chart for Compressive strength for Cube Speciemens on the

basis of Fiber Variations at28 Days.

4.3 *Flexural Strength*

The flexural strength for M60 Grade concrete, with Steel-Fiber mix concrete at 14 and 28 days is introduced in following figures. The test was done adjusting to IS 516-1959 to acquire the flexural strength of concrete at 14 days and 28 days. In this study, Steel Fiber mix concrete is compared with Normal OPC concrete mix and there results are described in following points. The flexural strength of concrete containing with Steel Fiber in M 60 grade respectively at 14 and 28 days curing is shown in Fig. 16. It can be seen by that the flexural strength of the concrete increases with increasing curing age. The flexural strength is up to 6.22 Mpa, 6.73 MPa and 8.53 Mpa, 9.37 MPa at 14 and 28 days respectively. The strength is increased by 8.20 % for M 60 grade with adding of 1 % steel fiber (based on cement content) at 7 days. The strength is increased by 9.85 % for M 60 gradewith adding of 1 % steel fiber (based on cement content)at 28 days.

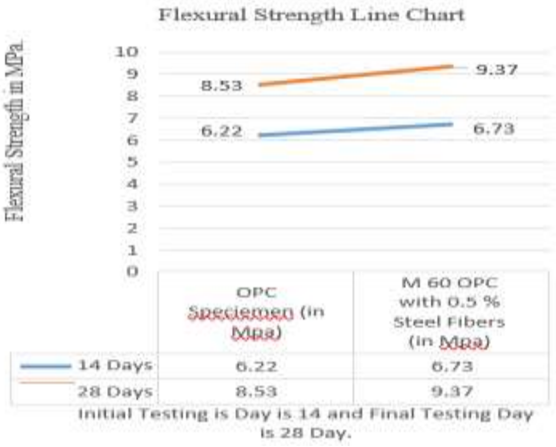

Figure 16 Comparison Chart of Split tensile strength of OPC Concrete Mix Speciemens and OPC Concrete Mix with Steel Fiber Speciemens. (Column Chart).

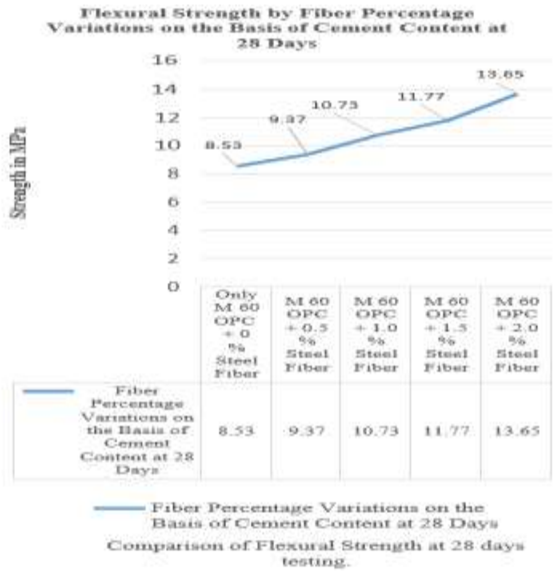

Figure 17 Line Chart for Split Tensile Strength for Cylinder Speciemens on the basis of Fiber Variations at 28 Days.

4.4 *Split Tensile Strength*

The split tensile strength M 60 grade concrete, with adding of steel fibers in concrete at 7 and 28 days is introduced in following figures. The test was done adjusting to IS 516-1959 to acquire the split tensile strength of concrete at 7 days and 28 days. In this study, is compared of normal opc concrete mix with steel fiber mix concrete mix. There results are described in followingpoints.

The split tensile strength of concrete containing steel fiber for M 60 respectively at 7 and 28 days curing is shown in Fig. 18. It can be seen by that the split tensile strength of the concrete increases with increasing curing age. The split tensile strength is up to 7.240 MPa (For OPC only at 7 days), 8.20 MPa (For OPC with Steel Fiber at 7 days), and 7.96 Mpa (For OPC only at 28 days), 8.44 Mpa (For OPC with Steel Fiber at 28 days) respectively. The strength is increased by 13.26 % for M 60 grade with adding of 1 % steel fiber (based on cement content) at 7 days. The strength is increased by 6.03 % for M 60 grade with adding of 1 % steel fiber (based on cement content) at 28 days.

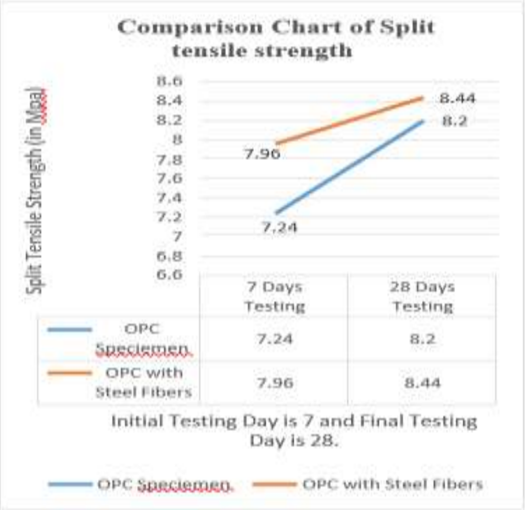

Figure 18 Comparison Chart of Split tensile strength of OPC Concrete Mix and OPC Concrete Mix with Steel Fiber. (Line Chart).

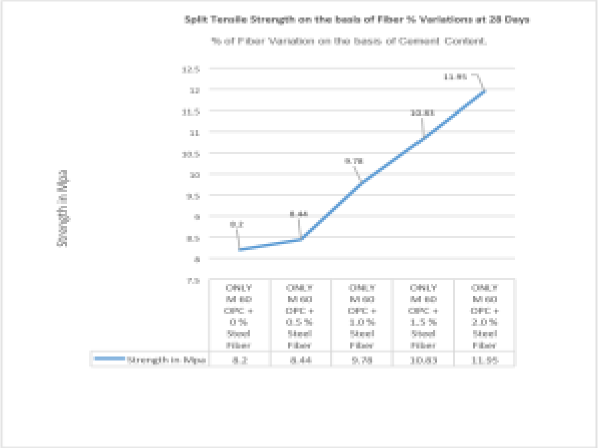

Figure 19 Line Chart for Split Tensile Strength for Cylinder Speciemens on the basis of Fiber Variations at 28 Days.

4.5 Carbonation Test

This test is performed at the interval of 14 days and 28 days after 28 days curing on the prepared specimens as per recommended guidelines of CPC-18 RILEM.

Carbonation depth increases with increase in the duration of exposure to CO_2.

In 14 days exposure testing there is little penetration could be seen in almost all the specimens made from different fiber percentages.

Carbonation depth is less in 14 days in M 60 opc and as well as similarly less in 2 % steel fiber added opc mix.

Carbonation depth is less in 28 days in M 60 opc and as well as similarly less in 2 % steel fiber added opc mix.

The reason of lesser carbonation depth due to more compactness of M 60 opc design mix.

These results are in good agreement with the compressive strength.

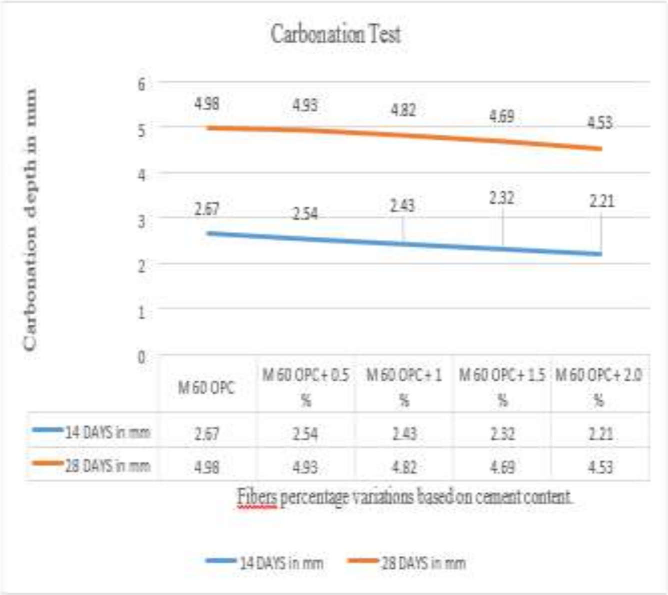

Figure 20 Line chart for variation carbonation depth test for cube speciemens on the basis of fiber content variations at 28 days adding in M 60 opc concrete mix.

V. CONCLUSIONS

The key purpose of this research was to explore the feasibility of using Steel Fiber in a concrete component. The compressive strength, flexural strength, split tensile strength were carried out to finding the effect of utilization of Steel Fibre on concrete mix. In this study, studies the effect of Steel Fiber added on concrete mix and thus change its properties. This would give a source for the utilization of Steel Fiber in the construction industry. The following conclusions were drawn on the basis of the observations.

a. The results on fresh concrete shows that Steel Fiber slightly reduces the workability of concrete. This may be due to more interlocking properties of Steel Fiber. Further desired workability of Steel Fiber added concrete mix can be achieved by using super plasticizers.

b. The following results are based on **2 % steel fiber of cement content after 28 days curing.**

c. The compressive strength is increased after by adding of Steel Fibers in M 60 Grade OPC mix is 16.23 % at 28 days.

d. The flexural strength is increased after by adding of Steel Fibers in M 60 Grade OPC mix is 60.02 % at 28 days.

e. The Split Tensile Strength is increased by 45.73 % for M 60 grade at 28 days.

f. Carbonation depth saw lesser penetration in Steel Fiber added concrete mix at 14 and 28 days of testing. As this shows there is no any harmful effect by Adding of Steel Fiber and Silica Fume in M 60 OPC Concrete Mix and shows decreasing result of carbonation depth than Normal M 60 OPC Concrete Mix.

g. Carbonation depth is seeing lesser of penetration in steel fiber added concrete mix after 14 and 28 days of testing due to high density of M 60 concrete mix design cube speciemens.

h. The carbonation depth is lesser after by adding of 2 % steel fibers in M 60 grade OPC mix is 9.036 % at 28 days.

i. So Above results show that there is also prevention from corrosion, weathering-action due to the use of high quality steel fiber. Thus rust or corrosion may remain far away for many years for these concrete speciemens.

j. Steel fiber added concrete mix shows improvements in hardened properties of concrete such as compressive strength, flexural strength, split tensile strength and carbonation test strength on 7, 14 and 28 days of testing for M 60 grade OPC.

k. The focus of this research is to increase strength of concrete mix in various manner for getting high heights in construction industry. This study examines the effect of using steel fiber with silica fume in high strength concrete mix i.e. M60.

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