ISSN 2277 – 5528
Impact Factor- 3.145

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

STEL FIBRE REINFORCED CONCRETE (SFRC)

Benke V.G.*1 , Shirsat M. N.*2 Sahane A.A. *3 Girme A. P.*4

*1 P.G. Student , M E. Structure, G.H.R.C.O.E ,Chas, Ahmednagar, India
*2 H. O. D.Civil Department G.H.R.C.O.E ,Chas, Ahmednagar, India
*3 P.G. Student , M E. Structure, A.V.C.O.E. Sangamner, India
*4P.G. Student , M E. Structure, G.H.R.C.O.E ,Chas, Ahmednagar, India

ABSTRACT

Cement concrete is probably the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be molded in any shape. Concrete consumption is around 10 billion tons per year, which is equivalent to 1 ton per every living person. Production of Cement and Steel has environmental hazards due to emission of CO_2 and dust particles in the atmosphere. Hence prudent use of cement and steel has distinct economic and environmental impacts. As we know, brittle failure is the inherent property of the plain concrete, i.e. it has very low tensile strength and low strain capacity at fractures. These shortcomings of plain concrete are overcome by adding reinforcing bars or prestressing steel. The main drawback of the reinforcing steel is corrosion due to the ingress of chloride ions in the concrete. Corrosion of steel bars forms rust with time. This rust is bigger in volume than iron which results in expansion. This expansion exerts large tensile stresses on concrete leading to the formation of cracks and thus propagation of these cracks leads to the spalling of concrete. To overcome this shortcoming, fibers are incorporated in cement concrete.

Keywords: *steel fibre, Mineral admixtures, Fly ash, ferromanganese.*

I. INTRODUCTION

This section should be typed in character size 10pt Times New Roman, Justified Quest for knowledge has not remained static. It could be from sheer inquisitiveness in the human nature in general or out of our needs. Researchers, scientists and technologists throughout the age have worked for advancement of knowledge. Researchers develop some idea and apply it to our advantage or to satisfy specific needs develop the appropriate equipment, material or technology. The field of concrete has no exception. There has been substantial advancement during last 90 years in the science and practices of our concrete technology out of which last 30 years have been phenomenal with1:2:4 volume mix and so on. For higher strengths in concrete we used to go in for M20 mix concrete and so on.

Cement concrete is probably the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be molded in any shape.

Plain cement concrete is the most widely used material for construction of various structures. However, it suffers from numerous drawbacks such as, low tensile strength, brittleness, unstable crack propagation and low fracture resistance etc. Addition of steel fibers to plain cement concrete results in improved structural properties, such as better resistance against cracking, impact, thermal shocks, wear, fatigue, spalling and improved compressive, flexural, tensile, shear, bond strengths, ductility and toughness. Hence, steel fibre reinforced concrete (SFRC) has been proved as a reliable and promising composite construction material having superior performance characteristics compared to conventional concrete.

Concrete consumption is around 10 billion tons per year, which is equivalent to 1 ton per every living person. Production of Cement and Steel has environmental hazards due to emission of CO_2 and dust particles in the atmosphere. Hence prudent use of cement and steel has distinct economic and environmental impacts.

Technically, it is possible to produce SFRC of very high tensile strength using high fiber content but it is not feasible for structural applications due to practical reasons. For e.g. the use of high fiber content leads to severe reduction of the workability of the fresh concrete. SFRC is limited to applications where crack distribution and reduction of crack widths are the main purpose. However, the combined use of SFRC and re-bars may yield synergetic effects due to improved bond properties. The use of SFRC as a building material has been the target of extensive research during the last decade but still the resulting impact on existing building codes is sparse. It is often argued that the relatively high material cost of fibers is the reason for the low usage, but the main reason is the current lack of design rules and guidelines which fully utilizes the advantages of SFRC. The fiber reinforced concrete is produced using different types of fibers. The fibers are mainly classified in two groups as metallic and non-metallic fibers. Here, we

ISSN 2277 – 5528
Impact Factor- 3.145

will mainly discuss Steel Fiber Reinforced Concrete (SFRC).

The SFRC is a composite material made of cement, fine and coarse aggregates and discontinuous discrete steel fibers. In tension SFRC fails only after the steel fiber breaks or pulled out of the cement matrix. The composite nature of SFRC is responsible for its properties in freshly mixed and hardened state. The SFRC possess many excellent dynamic performances such as high resistance to explosion and penetration as compared to traditional concrete. When used in structural applications, SFRC should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading and resist material disintegration.

The mechanical properties of SFRC are influenced by the type of fiber, aspect ratio, and volume fraction of fibers and the size of the aggregates. One of the most important properties of SFRC is its ability to transfer stresses across a cracked section which increases toughness of concrete in hardened state.

The above discussion has lead to the extensive research on concrete which has given us mineral admixtures (such as fly ash, silica fume, rice husk, etc.) to be partly used as cement replacement, super plasticizers to enhance the workability, different types of fibers incorporation in concrete which improves the mechanical properties, durability and serviceability of the structure.

Necessity:

As we know, brittle failure is the inherent property of the plain concrete, i.e. it has very low tensile strength and low strain capacity at fractures. These shortcomings of plain concrete are overcome by adding reinforcing bars or prestressing steel. The main drawback of the reinforcing steel is corrosion due to the ingress of chloride ions in the concrete. This problem becomes severe in coastal areas. Corrosion of steel bars forms rust with time. This rust is bigger in volume than iron which results in expansion. This expansion exerts large tensile stresses on concrete leading to the formation of cracks and thus propagation of these cracks leads to the spalling of concrete. To overcome this shortcoming, fibers are incorporated in cement concrete. There are different types of fibers available but here steel fibers are used because of their high tensile strength, ductility, ability to arrest propagation of cracks, improved bond strength, etc.

Extensive research has been done on SFRC using fly ash and silica fume as cement replacement but very little research has been conducted on SFRC using Fly ash. The present experimental work is mainly done to investigate the different strengths of SFRC using Fly ash as cement replacement. Silica fume and fly ash are the by-products and so has the uncontrolled engineering properties which sometimes don't give the required results. Instead, Fly ash is the manufactured product, produced by calsining fly ash at a temperature of 700 – 800^{0}c. Thus its controlled engineering properties yield good results regarding workability and durability of concrete. Silica fume or fly ash when blended with cement darkens the colour of concrete but Fly ash being white in colour doesn't alter the colour of concrete, thus enhancing aesthetic look.

The present experimental work is mainly concerned with the study of behavior of cement concrete by adding steel fibers and using mineral admixture- Fly ash as a cement replacement.

Fly ash at 15% by weight of cement and silica fume at 6 % by weight of cement and hooked type steel fibers with aspect ratio 80 are used for producing concrete. Fly ash has high pozzolanic reactivity and low price as compared to silica fume and fly ash as it is a manufactured product. It reduces free drying shrinkage and restrains the shrinkage cracking width. It also helps in enhancing the compressive strength and durability of concrete.

Addition of steel fibers to cement concrete enhances the overall strength properties of concrete as steel fibers have a relatively high strength and modulus of elasticity. In SFRC steel fibers used are hooked type as they are better than straight and crimped steel fibers. Hook end type fibers impart more ductility and enhance the bond with the cement matrix.

II. Selection of ingredients and mix design

General:

The ingredients of concrete, when selected and proportioned suitably, the above mentioned properties are realized in FAC. The main ingredients of FAC are as follows,

1) Cement.
2) Fine aggregates (i.e. sand).
3) Course aggregate.
4) Water.
5) Mineral admixtures (Fly Ash, Silica Fume)
6) Chemical admixtures (Super Plasticizers)

Material Properties:

Cement:

Among the chemical constituents of cement, the most important ones are C_3A, C_3S and C_2S. The C_3A portion of cement hydrates more rapidly, thereby reducing the workability of fresh concrete. It also adsorbs the chemical admixtures quickly which leads to reduction in availability of those admixtures for comparatively slower setting components of cement viz., C_2S and C_3S. This further affects the workability

ISSN 2277 – 5528
Impact Factor- 3.145

of fresh concrete and also its rate of retention of workability.

Regarding particle size distribution, it may be noted that finer particles hydrate faster than coarser particles and hence contribute more to early age strength concrete; however, at the same time, the faster the rate of hydration may lead to quicker loss of workability due to rapid and large release of heat of hydration.

After reviewing all above requirements, 43-grade 'ACC' ordinary Portland cement is used throughout the experimental work. Cement is tested in laboratory and results are as follows;

Table 1: Cement Properties.

Sr. No.	Description of Test	Results
01	Fineness of cement (residue on IS sieve No. 9)	3 %
02	Specific gravity	3.15
03	Standard consistency of cement	29 %
04	Setting time of cement a) Initial setting time b) Final setting time	100 minute 293 minute
05	Soundness test of cement (with Le-Chatelier's mould)	1.7 mm
06	Compressive strength of cement: a) 3 days b) 7 days	34.59 N/mm^2 56.08 N/mm^2

Fine Aggregate (Sand):

River sand is used as a fine aggregate. Among various characteristics (Table - 3.2), the most important one for FAC is its grading. Coarser sand may be preferred as finer sand increases the water demand of concrete and very fine sand may not be essential in FAC as it usually has larger content of fine particles in the form of cement and mineral admixtures such as fly ash, silica fume etc. Also the water demand because of addition of fiber. The sand particles should also pack to give minimum void ratio, as the test result show that higher void content leads to requirement of more mixing water.

Properties such as void ratio, gradation, specific gravity and bulk density have to be assessed to design a dense FAC mix with optimum cement content and reduced mixing water.

Coarse Aggregate:

The properties such as moisture content, water absorption, etc., would help in adjusting the quantity of mixing water for the FAC mix. The strength properties of CA such as Aggregate Abrasion value, Aggregate Impact value, Compressive strength, Aggregate Crushing value (10% fine value) etc. would determine the limits of strength of FAC which can be achieved with a given aggregate and these limits need to be investigated for creating database for rational design of FAC.

Locally available crushed stone aggregates with size 5mm to 12.5 mm and of maximum size 12.5 mm are used.

Water:

Water is an important ingredient of concrete as it actively participates in the from FAC mix design consideration, it is important to have the compatibility between given cement and chemical and mineral admixtures along with the water used for mixing. It is generally stated in the concrete codes and also in the literature that the water chemical reaction with cement. The strength of cement concrete comes mainly from the binding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of anhydrate cement as the excess water would end up in only formation of undesirable voids (and/or capillaries) in the hardened cement paste in concrete

From FAC mix design consideration, it is important to have the compatibility between given cement and chemical and mineral admixtures along with the water used for mixing. It is generally stated in the concrete codes and also in the literature that the water.

Water confirming to the requirements of IS-456: 2000 is suitable for making concrete. In the present work, available tap water is used for concreting.

Mineral Admixtures:

Necessity of use of Fly ash in Concrete:

India is experiencing an unprecedented growth of its urban centers due to its developing economy and industrialization. The characteristic feature of urbanization has been heavy concentration of urban population in large cities. This demands economical and efficient housing layout with multi storied buildings to be constructed in short duration.

Bearing in mind the increasing worldwide availability of PFA and rapidly decreasing source of natural and other good quality aggregates, fly ash can be used to produce aggregates (sometimes fly ash will be added to concrete as a fine aggregate). Use of fly ash not only reduces the problems created by it but is also beneficial in many other aspects. Today it is used as mineral admixture and acts as partial substitute for cement. Although the raw materials required for production of cement are generally available in almost all parts of world, Portland cement requires relatively costly materials in terms of energy expanded in its production. It is estimated that total energy consumed, including fuel cost, is about

7500 MJ/Tone for ordinary Portland cement where as it is only 150 to 400 MJ/Tones for fly ash. So use of PFA results in major savings of energy and raw materials. Replacement of each tone of cement saves at least 6000 MJ of energy, which is equivalent to a barrel of oil or a quartertone of coal.

Silica Fume:

Silica fume, also known as microsilica, is a byproduct of the reduction of high-purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys. Silica Fume is also collected as a byproduct in the production of other silicon alloys such as ferrochromium, ferromanganese, Ferro magnesium, and calcium silicon. Before the mid-1970s, nearly all Silica Fume was discharged into the atmosphere. After environmental concerns necessitated the collection and land filling of Silica Fume, it became economically justified to use Silica Fume in various applications.

Silica Fume consists of very fine vitreous particles with a surface area on the order of 20,000 m2/kg when measured by nitrogen absorption techniques, with particles approximately 100 times smaller than the average cement particle. Because of its extreme fineness and high silica content, Silica Fume is a highly effective pozzolanic material (ACI Comm. 226 1987b; Luther 1990). Silica Fume is used in concrete to improve its properties. It has been found that Silica Fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability; and therefore helps in protecting reinforcing steel from corrosion.

Chemical Admixtures:

Chemical admixtures are essentials ingredients in the concrete mix, as they increase the efficiency of cement paste by improving workability of the mix and thereby result in considerable decrease of water requirement. Thus w/c ratio as low as 0.30 or even less, the concrete mix can be cast. Though, there are many types of chemical admixtures are available, the following types are of more interest in the development of FAC mixes Superplasticizers,

However, any regular admixture, in practice, performs one or more of the above functions. Superplasticizers being surfactant in nature help to disperse the cement particles in the mix and thus the mobility/fluidity of the concrete mix is enhanced. Retarders reduce the initial rate of hydration of cement so that the fresh cement concrete retains its workability for a longer time. This requirement is important in case of FAC because FAC mixes tend to have larger cementitious content and lower water binder ratio, which may cause faster loss of workability.

Physical Properties of Steel Fibers:

Dramix steel fibers conforming to ASTM A 820 type-I are used for experimental work. Dramix RC - 80/60 - BN are high tensile steel cold drawn wire with hooked ends, glued in bundles & specially engineered for use in concrete. Fibers are made available from Shakti Commodities Pvt. Ltd., New Delhi. Dosages used 1% to 5% at the interval of 0.5 by weight of cement.

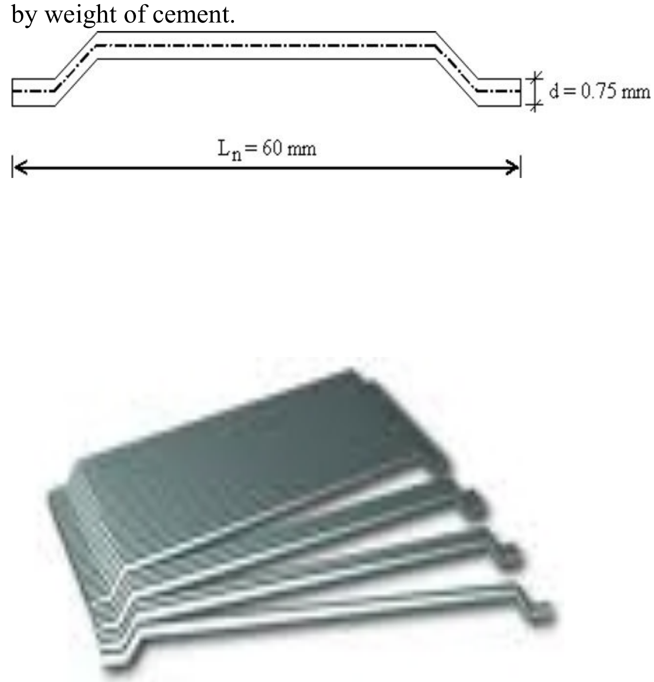


Fig: Steel Fiber with dimension details.

Table 2: Physical properties of Steel fibers.

Sr.no.	Property	Values
1.	Diameter	0.75 mm
2.	Length of fiber	60 mm
3.	Appearance	Bright in clean wire
4.	Average aspect ratio	80
6.	Deformation	Continuously deformed circular segment
7.	Tensile strength	1050 MPa
8.	Modulus of Elasticity	200 GPa
9.	Specific Gravity	7.8
10	Bond Factor	1

Mix Design of Concrete:

ACI method of mix design is used for mix design of M-30 grade of concrete. The optimum percentage of fly ash to give maximum compressive strength is achieved by making trial mixes with fly ash as cement replacement at a constant interval of 1% by weight of cement. The trial mixes were made for fly ash from1% to 20 %. The compressive strength went on increasing upto 15%. The maximum compressive strength is achieved at 15%. Hence, fly ash at 15% by weight of cement as cement replacement is used in this experiment. The quantity of ingredient materials and mix proportions as per design is as under

BIS Method (IS: 10262 - 1982):

a). The Code lists the grade of concrete unto M60 only, while suggesting the values of standard derivation each grade of concrete.

b). The graph of HIS Code suggesting the general relationship between water-cement (w/c) ratio and 28-day compressive strength refers to a maximum compressive strength of 52 MPa only and another graph the same relationship depending upon the 28-day strength of cement refer to a maximum compressive strength of 58 MPa. The FAC s usually has the compressive strength often more than 60 MPa. Hence, the above provision of BIS Code cannot be applied to FAC.

c) The extrapolation of standard deviations (SD) given in the Code to obtain SD for FAC, result in very high SD values. It is observed from the literature that the SD of HPCs would be quiet lower owing to the maximum care taken in selection of ingredients, proportioning, mixing, and curing FAC. Use of unrealistic high values of SDs would push up un-necessarily the cost of FAC s as the FAC s have to be designed for much higher strength than required.

d) The BIS method gives a table for finding water content of the concrete for w/c ratio of 0.35 only. In this table, water contents of 200 and 180 kg/m3 are suggested for maximum size of aggregates (MSAs) of 10 mm and 20 mm respectively. The FAC s usually have w/c = 0.3 or less. Even assuming w/c of 0.3 the cement contents corresponding to the above water contents work out to 667 and 600 kg/m3 respectively. These cements are too high and are never reported to be used for FAC as seen from the published literature on FAC.

e) Maximum w/c ratio of 0.45 suggested for 'severe' exposure condition in IS: 10262 and IS: 456 is too high and the FAC reported in the literature have very low w/c ratios (often 0.3 and below). Thus BIS suggestion of w/c = 0.45 cannot be accepted for FAC.

f). The suggestion of sand content at 28% (for MSA of 10 mm) and 25% (for MAs of 25 mm) in the BIS method leads to fine aggregate: coarse aggregate ratio of the order of 1:2 to 1:3 (by weight). From the published literature on FAC, these ratios (often 0.3 and below). Thus BIS suggestion of w/c = 0.45 cannot be accepted for HPCs ratios seem to be quiet high and hence, the cohesiveness of FAC would be affected if these ratios were adopted. As the FAC utilize SPs, it would be necessary to use more sand in order to avoid segregation of cement paste from aggregate due to dispersing / flowing effect of SP on the cement paste.

g). The BIS Code allows the use of Zone IV sand, which may have particle passing through 300 microns sieve, to an extent of 50%. As the FAC have usually a very lower content, this large content of small particles (less than 300 microns) of sand reduces the workability of the FAC. Moreover, the fine particles of sand may not be required in FAC as these concretes usually have high cement contents and also have often pozzolanic powdery materials such as FA, SF, etc.

ACI Method:

This Code covers 28-day compressive strength unto about 60 MPa as seen from the cure of compressive strength - V s - w/c ratio, suggested by this Code. The maximum w/c ratio covered is 0.3. As FAC have often strengths more than 60 MPa w/c 0.3 and below, the ACI method cannot give mix proportions for FAC.

IRC - 44 Method:

This method refers to a cure of compressive strength - Vs - w/c ratios in which minimum w/c ratio is 0.4 and maximum compressive strength is about 50 MPa. The FAC usually have w/c of 0.3 and less, which is quiet less than 0.4, the referred value in this method. The FAC usually have the strength more than 50 MPa. Thus, it can be seen that the IRC - 44 method cannot be used for the design of FAC mixes.

Thus it is observed from the study of conventional mix design methods (CMDs) that they are not generally applicable to SFRC because of the following reasons:

i) The compressive strength levels covered by CMDs are far less than those usually desired from FAC.

ii) W/c or w/b ratio of CMDs, are generally higher or quiet close to the highest level of w/b ratio encountered in FAC.

iii) The CMDs do not take in to account for changes in properties of fresh as well as hardened concrete due to incorporation of water reducing admixtures such as SP and also the permeability reducing mineral additives such as FA, SF, and GGBFSP, etc.

iv) The CMDs do not consider exclusively the durability aspects affecting properties of concrete such as porosity, impermeability, electric resistivity, etc

v) Many a time, type and strength of aggregate limit the strength level of FAC that can be achieved

ISSN 2277 – 5528
Impact Factor- 3.145

with the given aggregate. Such limitations are not usually encountered in case of CCC designed by the CMDs.

vii) The CMDs do not account for strength of transition zone. In FAC, consideration with regard to development of suitable transition zone needs special attention. Therefore the mix proportions for the FAC should be selected by trial and error *i.e.* by carrying out trail mixes by taking some proportions for desired strength. The technical report no.

Table 3: Quantity of Materials per Cubic Meter of Concrete.

Material	Proportion by Weight	Weight in Kg/m^3
Cement	1	500.0
F.A.	1.02	510.0
CAI (20mm) (60%)	1.224	612.0
CAII (10mm) (40%)	0.816	408.0
W/C	0.3	150.0

III. Experimental program

Aim of Experimental Work: The primary aim of this experimental program is to study the effect of silica fumes and fly ash content on the mechanical properties and non-mechanical properties of Steel fiber reinforced Concrete. Fly ash is used as mineral admixture and effect of different amount of Fly ash on the strength and durability related properties are studied.

Investigation of Concrete Properties:

Comparative study of effect of silica fumes and fly ash on Steel fiber reinforced concrete is done as far as following stated tests are concerned.

1) Workability (slump test).
2) Compressive strength test.
3) Flexural strength test.
4) Split tensile strength test.
5) Effective porosity test
6) Saturated water absorption test
7) Combine Effect of Shear and Torsion test on beam.

Casting of Steel Fiber Reinforced Concrete Specimens:

A) For Determination of Optimum Dose of Fly Ash and Silica Fume:

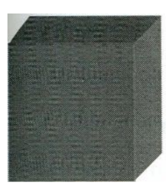
Cube moulds of 150 x 150 x 150 mm and cylindrical moulds of 150 mm diameter and 300 mm long are used for casting the specimen for compressive strength and split tensile strength test respectively. For flexure test, specimen size of 150 x 150 x 700 mm is cast. For shear and torsion test, specimen size of 100 x 150 x 1000 mm is cast.

The following table - 4.1 shows the details of casting of cube, cylinder and beam specimen for each w/c ratio.

Table 4 : Details of Specimens to Be Cast.

% Fly Ash	%Silica Fumes			Number Of Specimen		
				Cube	Cylinder	Beam
0	0	0.3	0.3	12	3	3
0	6	0.3	0.3	12	3	3
10	6	0.33	0.3	12	3	3
25	6	0.4	0.3	12	3	3
25	8	0.4	0.3	12	3	3
25	10	0.4	0.3	12	3	3
25	12	0.4	0.3	12	3	3

Preparations of Specimen:



Cube 150x150x150

Cylinder (150 x 300 mm)

ISSN 2277 – 5528
Impact Factor- 3.145

Beam (700 x 150 x 150 mm) For Flexure and Beam (1000 x 100 x 150 mm) For Shear

Fly ash is added to the cement first and then mixed thoroughly by hand to obtain a uniform mix. In order to obtain a uniform and effective mix of ingredients, prior to adding water in the concrete mix, coarse and fine aggregates and cement are mixed thoroughly by hand mixing. Later, water is added gradually for a period of about 2 min, concrete is then mixed for 3 min to produce a uniform mix.

Measurement of Ingredients:

All cement, sand, coarse aggregate (20mm), and coarse aggregate (10mm) measured with Digital balance. The water is measured with measuring cylinder of capacity 1 liter and measuring jar of capacity 1000ml, 2000 ml. The fly ash, plasticizer and steel fiber is measured with Digital balance of accuracy 1mg.

Mixing of Concrete:

The ingredients were thoroughly mixed over a G.I.sheet. The sand, cement and aggregate were measured accurately and were mixed in dry state for normal concrete. Whereas for fly ash concrete, first measured quantity of cement and required percentage of fly ash (e.g.12.5%) by weight of cement, were mixed thoroughly and then added to dry mix of aggregates. Similarly, for steel fiber reinforced concrete, the required quantities of steel fibers (i.e. from 0 % to 5%) were measured by weight of cement. The required weighted quantity of steel fibers is then uniformly sprinkled by hands on dry concrete mix containing CA, FA, cement and already mixed fly ash in cement. The dry concrete mix is then thoroughly and uniformly mixed till uniform and homogeneous mixing of fibers in dry mix is observed. Care is taken to avoid balling i.e. agglomeration of fibers. Selected percentage of super plasticizer is added to designed quantity of water and stirred vigorously so that it is mixed uniformly in the entire water. The solution is then spread over the concrete mix and remixed thoroughly again for few minutes

Workability of Concrete:

At every batch of mixing the concrete slump is measured and recorded with slump cone apparatus as per relevant IS.

Workability is measured in terms of slump. Results from Table (5.1), indicate that for same mix proportion and same SP dose with same aspect ratio of fiber but increase in fiber content (%) workability is reduced marginally.

Placing of Concrete:

The fresh concrete is placed in the moulds by trowel. It is ensured that the representative volume is filled evenly in all the specimens to avoid segregation, accumulation of aggregates etc. While placing concretes, the compaction in vertical position is given to avoid gaps in moulds.

Compaction of Concrete:

Moulds are cleaned and oiled from inside for smooth demoulding. Concrete is mixed thoroughly and placed in the mould in three layers and compacted by electrically operated Table vibrator with suitable fixing frame. It is vibrated till concrete woes out of mould. The vibration is continued till cement slurry just ooze out on surface of moulds. Care is taken of cement slurry not to spill over, due to vibration and segregation.

Finishing of Concrete:

After removing from vibrating table, the moulds were kept on ground for finishing and covering up for any leftover position. The concrete is worked with trowel to give uniform surface.

Care is taken not to add any extra cement, water or cement mortar for achieving good surface finish. The additional concrete is chopped off from top surface of the mould for avoiding over sizes etc. The density of fresh concrete is taken with the help of weigh balance. Identification marks are given on the specimens by embossing over the surface after initial drying.

Testing of Cube Specimens for Saturated Water Absorption (SWA):

The SWA was determined on 150 mm cube as per ASTM C-642 by drying the specimens in an oven at a temperature of 105^0 C to constant mass and then immersing in water after cooling to room temperature. The specimens were taken out of water at regular interval of times and weighed. The difference between the measured mass and oven dry mass expressed as a fractional percentage of oven dry mass gives the water absorption. The water absorption at the end *of* 120 hour was taken to be the SWA.

The SWA was determined by the formula,

$$SWA = 100x\frac{(WSM - ODM)}{(ODM)}$$

Where,

ISSN 2277 – 5528
Impact Factor- 3.145

WSM = Mass of specimen in water saturated condition achieved by submerging the specimen in water continuously till constant mass is attained over a regular interval of time.

ODM = oven dry mass obtained by drying the specimen in a hot air oven at a temperature of 105° C, till constant mass is achieved

Testing of Cube Specimens for Coefficient of Absorption:

The test for Coefficient of absorption was performed on 150 mm cube as suggested by Power. Power suggested the use of coefficient of absorption as a measure of permeability of water. This is measured by rate of uptake of water or capillary absorption of water by oven dry concrete in a period of 60 minutes and is computed as follows.

$$K_a = \left(\frac{Q}{A}\right)^2 x \frac{1}{t}$$

Where,

Ka = coefficient *of* absorption in *m²/s*

Q = quantity of water absorbed by the oven dry specimen in time.

t = 60 minutes.

A = total surface area of concrete specimen through which water penetrates.

Testing of Cube Specimens for Effective Porosity ( ):

The SWA is the measure of the pore volume or porosity in hardened concrete, which is occupied by water in saturated condition. It denotes the quantity of water, which can be removed on drying a saturated specimen. The porosity obtained from absorption test is designated as effective porosity.

The Effective porosity is determined on 150 mm cube by drying the specimens in an oven at a temperature of 105° C to constant mass and then immersing in water after cooling to room temperature. The specimens are taken out of water at regular interval of times and weighed. The submerged weights of the specimens are also calculated.

The Porosity of the specimens are determined by the formula,

= Effective Porosity of concrete = (V_v / V) x 100

Where,

V_v = volume of voids in the specimens determined as equivalent to volume of water lost by the specimens during the drying of the specimens at 105° C from water saturated condition of specimen

V_v = (WSM - ODM) / Density of water

V = Volume of specimen determined by loss in mass of the specimen due to displacement of water in submerged condition

= WSM – MSUB

M_{SUB} = Mass of specimen while submerged in water

$$\eta = \frac{(WSM - ODM)}{(WSM - M_{SUB})} x100$$

A slump test is performed on fresh concrete as per I. S. Provisions. Concrete made with 25% of Fly ash shows a higher slump in comparison to concrete made with 0% and 20% Fly ash. This is due to constant in the w/c ratio from the addition of fly ash and reduction in the cement content. The cube and cylindrical moulds are filled with concrete in three equal layers and each layer is tamped 25 times with a standard tamping rod. As the w/b ratio is kept very low as 0.3, the specimens are compacted by using table vibrator for two minutes to achieve a good and uniform compaction. After 24 hours all specimens are immersed in water.

Also, the beam moulds are filled with concrete in three layers and then top is finished off with a trowel. The specimens are removed from the moulds after 24 hours and cured in water. Prior to the testing, the specimens are tested under compression, split tension, flexure and fracture at 28 days. The beam specimen for flexure is tested under two points loading.

Curing:

All Cubes, Cylinders and Beams specimens are cured for 28 days in the water after 24 hours of casting

Table 5: Details of Specimens to Be Cast.

ISSN 2277 – 5528
Impact Factor- 3.145

% of steel fiber	W / C	W / B	Number Of Specimen		
			Cube	Cylinder	Beam
0.0	0.35	0.3	12	3	3
0.5	0.35	0.3	12	3	3
1.0	0.35	0.3	12	3	3
1.5	0.35	0.3	12	3	3
2.0	0.35	0.3	12	3	3
2.5	0.35	0.3	12	3	3
3.0	0.35	0.3	12	3	3
3.5	0.35	0.3	12	3	3
4.0	0.35	0.3	12	3	3
4.5	0.35	0.3	12	3	3
5.0	0.35	0.3	12	3	3

For Determination of Optimum Dose of Steel Fibers:

(Keeping aspect ratio constant)

Table 6: Details of Specimens to Be Cast.

% Steel Fiber	W/C	% Fly Ash	% Silica Fumes	Beam W/ R	Beam W.R
0.0	0.35	15	6	3	3
0.5	0.35	15	6	3	3
1.0	0.35	15	6	3	3
1.5	0.35	15	6	3	3
2.0	0.35	15	6	3	3
2.5	0.35	15	6	3	3
3.0	0.35	15	6	3	3
3.5	0.35	15	6	3	3
4.0	0.35	15	6	3	3
4.5	0.35	15	6	3	3
5.0	0.35	15	6	3	3

Test Setup:

Testing of Cube Specimens for Compressive Strength:

For the compression test, the cubes are placed in machine in such a manner that the load is applied on the Forces perpendicular to the direction of cast. In Compression testing Machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted. Also the failure pattern is observed precisely.

Table 7: Details of Specimens to be cast for Optimum Dose of Fly Ash and varying percentage of Steel fiber for shear and torsion.

% Steel Fiber	W/C	% Fly Ash	% Silica Fumes	Beam W/R	Beam W.R
0.0	0.35	15	6	3	3
0.5	0.35	15	6	3	3
1.0	0.35	15	6	3	3
1.5	0.35	15	6	3	3
2.0	0.35	15	6	3	3
2.5	0.35	15	6	3	3
3.0	0.35	15	6	3	3
3.5	0.35	15	6	3	3
4.0	0.35	15	6	3	3
4.5	0.35	15	6	3	3
5.0	0.35	15	6	3	3

Testing of Cylinder Specimens for Split Tensile Strength:

For determining split tensile strength, cylinder specimens are placed between the two plates of Compression Testing Machine. Plywood strips of 3 mm thick, 25 mm wide and 300 mm long, are placed between the plates and surface of the concrete specimens. The load is applied at a uniform rate till the specimen failed by a fracture along vertical diameter.

The split tensile strength is calculated from the formula, $t = 2P/\pi DL$, where P is the load at failure and D and L are the diameter and length of specimen, respectively

Testing of Beam Specimens for Flexure:

In flexure test, the beam specimen is placed in the machine in such a manner at the load is applied to the upper most surface as cast in the mould. All beams are tested under two-point loading in Universal Testing Machine of 100-tonne capacity. The load as increased until the specimen failed and the failure load is recorded. The adjoining shows the flexural strength test setup for the beam.

The flexural strength is calculated from the formula

$_b = PL / bd^2$

Where, P = the applied load at failure and,
d = depth of specimen,
b = breadth of specimen and
L = Length of specimen respectively.

Shear and Torsion test:

The experimental investigation consisted of casting and testing 33 steel fiber reinforced concrete beams under combined effect of shear and Torsional loading, out of 66, 33 beams are without reinforcement & remaining 33 with reinforcement.

The size of each beam is 1000 x 100 mm x 150 mm. The variables include the over reinforced state of the cross section and volume fraction of the fiber. The volume fraction of the fiber content is 0 % to 5 % weight of cement in the interval of 0.5 %.

The proportioning of concrete is maintained constant throughout the investigation. A concrete mix targeting a compressive strength of 30 MPa is used. Figure 1 shows the cross sectional details of the beam loading arrangement. An effective cover of 15 mm is provided for the transverse reinforcement.

The cured beams are white washed a day before testing to facilitate the crack identification. One end of the beam is supported on rollers, while the other end is supported on rigid support. This type of test setup Facilitates free rotation of roller end and provides stability to the test specimen during testing. Specially made twist arms or twist angles are placed at both supports of the beam having an arm length of 0.60 m. Load on the twist arm is applied through a Hydraulic jack and the loading is monitored through a proving ring attached to the jack. Absolute care has taken, such that, the plane of loading and twisting arm are perpendicular to the longitudinal axis of the beam. This avoids any possibility of bending of the beam instead of twisting and as a result the beam between the two supports is subjected to pure torsion. The complete test setup is schematically presented in Photo.4.1. Shows the actual test set up. Load is applied at an eccentricity of 0.66 m from the center of the beam. For every applied load, the corresponding dial gauge readings are noted. Which were placed al L/3 distance from both end and considering average of two readings.

Fig: Typical setup For Shear& Torsion Test.

IV. Test Results And Discussion

The results obtained by carrying out the tests on the cubes, cylinders and beams made with mix proportions decided earlier are as stated below.

Compressive Strength:

As expected the compressive strength increases with increase in content of fly ash. As the total water/binder ratio is kept constant, the variation of strength with respect to water/cement ratio remains open to discussion. The curve plotted denotes that the optimum dose of fly ash is 15 % for 41.58 MPa compressive strength.

Also the increase in silica fume content results in increase in the compressive strength up to meager extent. The optimized dose of silica fume found is 6 % of cement replacement for the compressive strength.

Split Tensile Strength:

The split tensile strength for w/c ratio of 0.3 to 0.4 varies from 12.8 to 18.3 % of its compressive strength. The higher tensile strength is due to reason that the full capacity of aggregate strength is utilized and also due the denser binding matrix forms by addition of fly ash. Addition of fly ash and silica fumes increases the split tensile strength of concrete. The experiments denote the sudden failure of material i.e. it didn't showed any hair crack propagation before failure.

Flexural Strength:

The test results show that the same w/b content, there was increase in flexural strength with increase in percentage of fly ash. The addition of fly ash and silica fume improves the cracking strength of concrete. The fly ash produces the denser concrete, resulting in better strength. The maximum increase of 14% obtained for 15% addition of fly ash and 6% silica fumes in concrete, having w/b ratio 0.3, the test results were also compared with the recommended values of IS 456-2000, shows that a higher value of flexural strength is observed in case of fly ash concrete. This is due to the fact that in fly ash

ISSN 2277 – 5528
Impact Factor- 3.145

concrete full capacity of aggregates is utilized and also the addition of mineral admixtures such as fly ash and silica fume increases the flexural strength. Thus it can be stated that the codal provision cannot be applied to fly ash concrete and suitable provisions has to be made for fly ash concrete in the codes.

Saturated water absorption:

Saturated water absorption for w/c ratio 0.3 to 0.4 varies from 3.22 to 3.749. It is observed that the lowered values of saturated water absorption are observed in case of concrete made with addition of fly ash and silica fumes. This is due to the Fact that addition of fly ash makes the binding material denser and reduces the permeability of concrete.

Coefficient of Absorption:

Saturated eater absorption for w/c ratio of 0.3 to 0.4 varies from 2.73 x 10^{-10} to 0.784x 10^{-10} m^2/sec. from the test results as expected it has been observed that addition of fly ash in the concrete mixes gives lower values of coefficient of absorption. Fly ash and silica fumes based mixes show 30 to 55 % reduction in coefficient of absorption. Since the coefficient of absorption corresponds to the rate of uptake of water in first hour of exposure to water, it can be preferred that the capillary pores have less inter connectivity in fly ash based concrete.

From the above discussion it is concluded that the concrete giving maximum strength for 15 % replacement of fly ash and 6 % addition of silica fume.

Shear Strength:

The shear strength of SFRC beam increases with increase in content of steel fibers. There is increase in the strength is up to certain percentage of steel fibers after that the there is reduction in the strength. For 2.18 % of steel fibers the beam giving highest strength of 3.97 kN for with ought reinforced and for 4.07 % of steel fiber gives the highest strength of 8.46 kN It shows that even the percentage of steel fiber is more in case of reinforced beam but the shear resistance capacity is nearly twice of the plain concrete beam. Average increasing in strength for without reinforcement and with reinforcement is 62% and 160%.

Experimental Moment:

The moment of SFRFC beam increases between 4 to 5 % of steel fibers. The higher moment is due to reason that the steel fibers resisting the load. From the observations and graphs it is concluded that the steel fiber volume of 4.08 % and 4.20% of steel fiber giving maximum moment 2.59 kN-m and 2.91 kN-m. Average increasing in moment for without reinforcement and with reinforcement is 84% and 94%.

Torsional Moment:

The results showing gradual increase in torsional strength upto certain percentage of addition of steel fibers. After that there is decrease in the strength. The observation shows that addition 2.21% and 2.07 % of steel fibers gives maximum torsional strength of 31.02 kN-m and 30.16 kN-m for with and without reinforcement.

Percentage of fibers for both experimental moment (flexural moment) and torsional moment with and without reinforcement is nearly same because the reinforcement is longitudinal and it is having very less contribution to resist the rotation.

Average increasing in moment for without reinforcement and with reinforcement is 52.09% and 53.58%.

V. CONCLUSION

Chapter presents a summary of present study, the major conclusions and future scope of the investigation with the applications of SFRC.

Following conclusion are drawn based on the result discussed in the previous chapter:

The wet and dry density at 7 and 28 days has increased marginally for fly ash concrete over normal PCC. This may be due to partial cement replacement by fly ash, which dandifies the concrete because of its micro filler effect due to the relatively finer particle size.

The mechanical properties of concrete are enhanced with the addition of fly ash. All the properties of concrete like compressive strength, split tensile strength and flexural strength is increased. Also there is reduction in porosity as well as reduction in absorption capacity of the concrete as compared with normal concrete.

From the results and discussion it shows that for 15 % replacement of fly ash with 6 % addition of silica fume, concrete showing overall improvement.

In general, the significant improvement in various strengths is observed with the inclusion of Hooked end steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.

Satisfactory workability is maintained with addition of fly ash and silica fume by using super plasticizers.

The optimum percentage fibre volume fraction for compressive strength, flexural strength and split tensile strength is up to 2.825%.

With increasing fibre content, mode of failure is changed from brittle to ductile failure when subjected to compression and bending.

The strength models developed for SFRC predicts the results of various strengths which are in good compliance with experimental results.

The properties like shear, torsion and bending is also improved due to addition of fibers in the concrete. This is obvious because the addition of fibers resists the development of internal micro crack in the concrete, which are responsible for the failure of the structure.

The optimum dose fiber for shear is 2.18 % and 4.07 % for with and without reinforcement respectively.

For torsional moment 2.21 % and 2.07 % volume fibers gives optimum strength. It concludes that the longitudinal reinforcement in the beams having less resistance in shear, torsion and moment.

REFERENCES

1. *Job Thomas and Ananth Ramaswamy, "Mechanical Properties of Steel Fiber-Reinforced Concrete", Journal of Materials in Civil Engineering, Vol. 19, No. 5, May 1, 2007, pp. 385-389.*
2. *Fuat Koksal, Fatih Altun,Ilhami Yigit,Yusa Sahin, " Combined effect of silica fume and steel fiber on the mechanical properties of high strength concretes". Construction and Building Materials, Vol. 22, No. 8, 2008, pp. 1874–1880.*
3. *Semis Azoic, Gozde Inan and Volkan Tabak, "Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC". Construction and Building Materials, Vol. 21, 2007, pp. 1250–1253.*
4. *Calogero Cucchiara, Lidia La Mendola and Maurizio Papia, "Effectiveness of stirrups and steel fibers as shear reinforcement". Cement and Concrete Research, Vol.26, 2004, pp. 777-786.*
5. *Banthia N., Sappakittipakorn M., "Toughness enhancement in steel fiber reinforced concrete through fiber hybridization". Cement and Concrete Research, Vol. 37, 2007, pp.1366 – 1372.*
6. *Sivakumar A., Manu Santhanam, "Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibers". Cement & Concrete Composites, Vol. 29, 2007, pp. 603–608.*
7. *Bayramov F., Tasdemir C. and Tasdemir M.A., "Optimizations of steel fiber reinforced concretes by means of statistical response surface method". Cement & Concrete Composites, Vol. 26, 2004, pp. 665–675.*
8. *Fuat Koksal, Fatih Altun,Ilhami Yigit,Yusa Sahin, " Combined effect of silica fume and steel fiber on the mechanical properties of high strength concretes". Construction and Building Materials, Vol. 22, No. 8, 2008, pp. 1874–1880.*
9. *Padmarajaiah S.K. and Ananth Ramaswamy, "Flexural strength predictions of steel fiber reinforced high-strength concrete in fully / partially prestressed beam specimens". Cement & Concrete Composites, Vol. 26, 2004, pp. 275–290.*
10. *Song P.S. and Hwang S., "Mechanical properties of high-strength steel fiber-reinforced concrete". Construction and Building Materials, Vol 18, 2004, pp. 669–673.*
11. *Hong-Sam Kim, Sang-Ho Lee and Han-Young Moon, "Strength properties and durability aspects of high strength concrete using Korean Fly Ash". Construction and Building*
12. *ACI Committee 544, "State-of- the- Art Report on Fiber Reinforced Concrete", American Concrete Institute, 1996, pp.1-66.*
13. *ACI Committee 544, "Guide for Specifying, Proportioning, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete", American Concrete Institute, 1993 (Reapproved 1989), pp.1-11.*
14. *I.S.12269 - 1987, "Specification for 53 Grade Ordinary Portland Cement", Bureau of Indian Standard, New Delhi, 1988.*
15. *I.S.456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete, (fourth Revision)", Bureau of Indian Standard, New Delhi, 2000.*
16. *I.S.10262-1982, "Indian Standard Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standard, New Delhi, 1983.*
17. *I.S.516-1975, "Method of Tests for Strength of Concrete", Bureau of Indian Standard, New Delhi.*
18. *Mansur M.A. Bending-torsion interaction for concrete beams with steel fibers. Magazine of Concrete research, London, vol. 34, No. 121, December 1982. PP 182-190.*
19. *Mansur M.A. and Paramasivam P. Steel fiber reinforced concrete beams in torsion, bending and shear. Journal of American Concrete institute proceedings, vol.82, No.1, January-February 1985. pp 33-39.*