

# **A Comparative and Experimental Study on the Mechanical Properties of Various Steel and Glass Fiber Reinforced High Strength Concrete**

CH. Raj Kumar<sup>1</sup>, K. Midhun Kumar <sup>2</sup>, S.Madan Mohan <sup>3</sup>, Dr. S. Sreenatha Reddy<sup>4</sup>

PG Student, Dept. of Civil Engineering, Gurunanak Institute of Technology, Rangareddy, Telangana, India<sup>1</sup>

Assistant Professor, Dept. of Civil Engineering, Gurunanak Institute of Technology , Rangareddy, Telangana , India<sup>2</sup>

Professor, Dept. of Civil Engineering, Gurunanak Institute of Technology, Rangareddy, Telangana , India<sup>3</sup>

Professor, Dept. of Mechanical Engineering, Gurunanak Institute of Technology, Rangareddy, Telangana , India<sup>4</sup>

**ABSTRACT:** Cement concrete is the most extensively used construction material in the world. It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of hooked steel, crimped steel & glass fiber reinforced concrete is its superior resistance to cracking and crack propagation. Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are dispersed uniformly. The fibers used in FRC may be of different materials like steel, G.I., carbon, glass, aramid, asbestos, polypropylene, jute etc. FRC has found many applications in civil engineering field. Based on the laboratory experiment on fiber reinforced concrete (FRC), cube and cylinders specimens have been designed with steel fiber reinforced concrete (SFRC) and Glass fiber reinforced concrete (GFRC) containing fibers of 0% and 0.5% volume fraction of hook end Steel fibers of 53.85, 50 aspect ratio and alkali resistant glass fibers containing 0% and 0.25% by weight of cement of 12mm cut length were used without admixture.

In this paper effect of fibers on the different mechanical properties of grade M-40 have been studied. It optimizes 1.5% for steel Fiber content and 1% for glass fiber content by the volume of cement is used in concrete. The percentage increase in compressive strength at 28 days for hooked end steel fiber when compared to conventional concrete is 7.3%, crimped steel fiber with 6.08%, glass fiber with 4.3. The percentage increase in split tensile strength at 28 days hooked end steel fiber when compared to conventional concrete is 4.54%, crimped steel fiber with 3.40%, glass fiber with 2.27% and also The percentage increase of flexural strength at 28 days for hooked end steel fiber when compared to conventional concrete is 3.57%, crimped steel fiber with 2.380%, glass fiber with 2.140%.

**KEYWORDS:** Steel fiber reinforced concrete (SFRC) and Glass fiber reinforced concrete (GFRC), High strength concrete, M-40 Grade, IS:1386, IS:38

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

## I. INTRODUCTION

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail.

The formation of cracks is the main reason for the failure of the concrete. To increase the tensile strength of concrete many attempts has been made. One of the successful and most commonly used methods is providing steel reinforcement. Steel bars, however, reinforce concrete against local tension only. Cracks in reinforced concrete members extend freely until encounter ring are bar. Thus need for multidirectional and closely spaced steel reinforcement arises. That cannot be practically possible. Fiber reinforcement gives the solution for this problem. So to increase the tensile strength of concrete a technique of introduction of fibers in concrete is being used. These fibers act as crack arrestors and prevent the propagation of the cracks. These fibers are uniformly distributed and randomly arranged. This concrete is named as fiber reinforced concrete. The main reasons for adding fibers to concrete matrix is to improve the post cracking response of the concrete, i.e., to improve its energy absorption Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers FRC increases the tensile strength of the concrete, it reduce the air voids and water voids the inherent porosity of gel. It increases the durability of the concrete. Fibers such as graphite and glass have excellent resistance to creep.

## II. RELATED WORK

The concept of using fibers in a brittle matrix was first recorded with the ancient Egyptians who used the hair of animals and straw as reinforcement for mud bricks and walls in housing. This dates back to 1500 B.C. (Balaguru et al, 1992).

Ronald F. Zollo (1997) presented an overview regarding the history and development of Fiber Reinforced Concrete 30 years ago. According to this report, in the early 1960s, the works on fiber reinforced concrete had been started. A lot of research work has been conducted by many researchers on different fashions. But these projects have studied about steel fibers alone. So far, there were only a few works which have studied the other fibers like nylon, plastic, rubber and natural fibers. But those researches are completely according to the terminology adopted by American Concrete Institute (ACI) Committee 544, there are four categories of fiber Reinforced Concrete namely

- 1) SFRC (Steel Fiber Reinforced Concrete),
- 2) GFRC (Glass Fiber Reinforced concrete),
- 3) SNFRC (Synthetic Fiber Reinforced Concrete) and
- 4) NFRC (Natural Fiber Reinforced Concrete).

It also provides the information about various mechanical properties and design applications. Cement and Concrete Institute also published the classification of FRC in their website. Based on their classification, Fibers are classified into Glass, Steel, Synthetic (includes Acrylic, Aramid, Carbon, Nylon, Polyester, Polyethylene, Polypropylene) and Natural Fibers.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

## III. MATERIALS USED

### Fiber Reinforced Concrete

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. So we can define fiber reinforced concrete as a composite material of cement concrete or mortar and discontinuous discrete and uniformly dispersed fiber. Fiber is discrete material having some characteristic properties. The fiber material can be anything. But not all will be effective and economical. Some fibers that are most commonly used are:

- Steel
- Glass
- Carbon
- Natural
- NBD

Steel fiber is one of the most commonly used fiber. Generally round fibers are used. The diameter may vary from 0.25 to 0.75mm. The steel fiber sometimes gets rusted and lose its strength. But investigations have proved that fibers get rusted only at surfaces. It has high modulus of elasticity. Use of steel fibers makes significant improvements in flexure, impact and fatigue strength of concrete. It has been used in various types of structures.

Glass fiber is a recently introduced fiber in making fiber concrete. It has very high tensile strength of 1020 to 4080Mpa. Glass fiber concretes are mainly used in exterior building façade panels and as architectural precast concrete. This material is very good in making shapes on the front of any building and it is less dense than steel. Use of carbon fiber is not a developed process. But it has considerable strength and young's modulus. Also investigations have shown that use of carbon makes the concrete very durable. The study on the carbon fibers is limited. Mainly used for cladding purpose.

Natural fibers are low cost and abundant. They are nonhazardous and renewable. Some of the natural fibers are bamboo, jute, coconut husk, elephant grass. They can be used in place of asbestos. It increases toughness and flexural strength. It also induces good durability in concrete.

Disposal of non biodegradable materials is a serious problem. It creates environmental problems. Reusing is the best option to reduce the waste. These NBD materials are non corrosive, resistant to chemical attack, light in weight, easy to handle NBD materials – fiber plastic, jute plastic, polythene, disposal glass, cement bags. Studies conducted so far, proved that the short and discrete, small fibers can improve the flexural load carrying capacities and impact resistance for non ferrous fibers.

### Behavior of Steel Fiber Reinforced Concrete under Flexure :

In numerous investigations, it has been displayed that the flexure, shear, torsion, punching, dynamic impact behavior of structural elements improved by the use of Steel Fiber Reinforced Concrete.

- Increases moment capacity,
- Increase cracking moment,
- Increase the ductility,

# International Journal of Innovative Research in Science, Engineering and Technology

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 5, Issue 9, September 2016**

- Increases crack control,
- Increases rigidity,
- Increase strength,
- Increase capacity,
- Preserves the structural integrity after beam exceeds the ultimate load.

## **The applications of Steel Fiber reinforced concrete:**

- Tunnel linings
- Manholes,
- Risers,
- Burial Vaults,
- Septic Tanks,
- Curbs,
- Pipes,
- Covers,
- Sleepers
- Roller compacted concrete with steel fibers

## **Applications of Glass Fiber Reinforced Concrete:**

Commercially, GFRC is used to make large, lightweight panels that are often used as façades. These panels are considered non-structural, in that they are designed to support their own weight plus seismic and wind loadings, much in the way glass window curtain walls are designed. The panels are considered lightweight because of the thinness of the material, not because GFRC concrete has a significantly lower density than normal concrete. On average it weighs about the same as ordinary concrete on a volume basis.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

## IV. PROPOSED METHODOLOGY

In order to study the interaction of Steel fibers (hooked end) with concrete under compression, flexure, split tension and impact, 8 cubes, 8 beams and 16 cylinders were casted respectively. The experimental program was divided into four groups.

Each group consists of 2 cubes, 4 cylinders and 2 beams, of 15x15x15cm, 15(dia) x30cm and 15x15x70cm respectively. The first group is the control (Plain) concrete with 0% fiber (PCC)  
The second group consisted of 1% of Steel fibers (hooked end), with aspect ratio 80, by volume.  
The third group consisted of 2% of Steel fibers (hooked end), with aspect ratio 80, by volume.  
The fourth group consisted of 3% of Steel fibers (hooked end), with aspect ratio 80, by volume.

**Cement** : Locally available Ordinary Portland Cement of 53 grade of ULTRATECH Cement brand confirming to ISI standards has been procured and following tests have been carried out.

**Fine Aggregates** :The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement]. The fine aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density.

- Specific gravity
- Density
- Grading
- Fineness modulus of Fine aggregate

**Coarse Aggregate** : The coarse aggregate chosen for SCC was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self compacting concrete was between 10mm to 16mm. The rounded and smaller aggregate particles provide better flow ability and deformability of concrete and also prevent segregation. Graded aggregate is also important particularly to cast concrete in highly congested reinforcement or formwork having small dimensions. Crushed granite metal of sizes 16 mm to 10 mm graded obtained from the locally available quarries was used in the present investigation. These were tested as per IS 383-1970 [Methods of physical tests for hydraulic cement].

**Water** : Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS : 3025 – 1964 part22, part 23 and IS : 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

**Fly Ash** : Fly ash is one of the most extensively used supplementary cementitious materials in the construction field resembling Portland cement. It is an inorganic, non combustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace. Most of the fly ash particles are solid spheres and some particles, called cenospheres, are hollow and some are the plerospheres, which are spheres containing smaller spheres inside. The particle sizes in fly ash vary from less than 1  $\mu\text{m}$  to more than 100  $\mu\text{m}$  with the typical particle size measuring less than 20 $\mu\text{m}$ . Their surface area is typically 300 to 500  $\text{m}^2/\text{kg}$ , although some fly ashes can have surface areas as low as 200  $\text{m}^2/\text{kg}$  and as high as 700  $\text{m}^2/\text{kg}$ . Flyash is primarily silicate glass containing silica, alumina, iron, and calcium. The relative density or specific gravity of flyash generally ranges between 1.9 and 2.8 and the color is generally grey.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

## Mixing and Casting :

For each mix, the required quantities of the constituents were batched by weight and concrete was mixed in a 50 kg capacity drum type mixer in the laboratory. Before starting mixer machine, the mixer drum was fully washed and allowed for few minutes to dry the drum. Coarse aggregate were first placed and mixed with 40% of the calculated water for one minute. Then the fine aggregate and 30% of the water is added along with the super plasticizer. The mixing was continued for two minutes. Finally the cement, Fly ash , Silica Fume and the remaining water were added and mixing as continued until the fresh concrete become homogeneous.

During assembling of the mould for use, the joints between the sections of mould were thinly coated with crude oil and a similar coating of crude oil was applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling of concrete. The interior surfaces of the assembled mould also are thinly coated with crude oil to prevent adhesion of the concrete.

Test specimens were made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. Compaction was done by means of an electric vibrating table. After the top layer has been compacted, the surface of the concrete was finished level with the top of the mould, using a trowel, and covered with plastic sheets for 24 hours to prevent the evaporation of water from the concrete. They were demoulded after 24 hours and cured in water at the room temperature of 25 - 280C until testing.

## Design Of M40 Grade High Strength Concrete By DOE Method:

### Materials:

Cement : OPC 53 grade

Coarse aggregates : crushed stone

Fine aggregates : natural river sand

Properties of materials:

|                           |   |                         |
|---------------------------|---|-------------------------|
| Cement                    | : | specific gravity= 2.99  |
| Coarse aggregates         | : | fineness modulus = 7.14 |
| Bulk specific gravity     | = | 2.64                    |
| Absorption characteristic | = | 0%                      |
| Fine aggregates           | : | fineness modulus = 2.78 |

Absorption characteristic = 1%

### Parameters:

Assume standard deviation = 5N/mm<sup>2</sup>

Assume slump of concrete = 75mm

Target mean strength = specific characteristic strength+ standard deviation × risk factor

$40 + (5 \times 1.65)$

48.25 Mpa

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

### V. EXPERIMENTAL RESULTS

#### Compressive Strength Results:

| Sl. No | Cubes Casted Day | Conventional concrete (N/mm <sup>2</sup> ) | Hooked end steel fiber (N/mm <sup>2</sup> ) | Crimped steel fiber(N/mm <sup>2</sup> ) | Glass fiber(N/mm <sup>2</sup> ) |
|--------|------------------|--|---|---|---------------------------------|
| 1      | 3rd day          | 14   | 21.75                                       | 19.3                                    | 18                              |
| 2      | 7th day          | 26   | 28  | 30.4                                    | 29.4                            |
| 3      | 28th day         | 47.4                                       | 48  | 47.2                                    | 46.2                            |

#### Flexure Test Results:

| Sl. No | Beams casted day | Conventional Concrete | Hooked end steel Fiber | Crimped steel fiber | Glass fiber |
|--------|------------------|-----------------------|------------------------|---------------------|-------------|
| 1      | 3rd day          | 0.7                   | 1.6                    | 1.2                 | 2.1         |
| 2      | 7th day          | 2.7                   | 3.2                    | 2.8                 | 3.0         |
| 3      | 28th day         | 5.4                   | 5.7                    | 5.6                 | 5.5         |

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

**Split Tensile Strength Results:**

| Sl. No | Cylinders<br>casted day | Conventional<br>Concrete<br>(N/mm <sup>2</sup> ) | Hooked<br>end steel<br>Fiber<br>(N/mm <sup>2</sup> ) | Crimped<br>steel fiber<br>(N/mm <sup>2</sup> ) | Glass fiber<br>(N/mm <sup>2</sup> ) |
|--------|-------------------------|--|--|--|-------------------------------------|
| 1      | 3 <sup>rd</sup> day     | 0.9  | 1.6  | 1.4  | 1.3                                 |
| 2      | 7 <sup>th</sup> day     | 2.2  | 2.7  | 2.3  | 2.2                                 |
| 3      | 28 <sup>th</sup> day    | 5.8  | 6.2  | 6.1  | 6.0                                 |

## VI. CONCLUSIONS

The present study is about using different fibers i.e., crimped steel fibers hooked steel fibers and glass fibers after optimizing them; comparison is made between the three fibers for different mechanical properties.

- The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 7.3%. And the increasing percentage of compressive strength of crimped steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 6.08%. And The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cubes when compared to the conventional concrete cubes at 28 days is 4.34%.
- The increasing percentage of split tensile strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 4.54%. And the increasing percentage of split tensile strength of crimped steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 3.40%. And The increasing percentage of compressive strength of hooked end steel fiber reinforced concrete cylinders when compared to the conventional concrete cylinders at 28 days is 2.27%.
- The increasing percentage of flexural strength of hooked end steel fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 3.57%. And the increasing percentage of flexural strength of crimped steel fiber reinforced concrete beams when compared to the conventional beams at 28 days is 2.380%. And The increasing percentage of flexural strength of glass fiber reinforced concrete beams when compared to the conventional concrete beams at 28 days is 2.140%.



# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

## REFERENCES

1. ACI 234R-06 "Guide for the use of Silica Fume in Concrete". American Concrete Institute.
2. ACI 544.1R-96, (Reapproved 2009) "Report on fiber reinforced concrete". American Concrete Institute.
3. ACI 544.4R-88, "Design Considerations for Steel Fiber Reinforced Concrete". American Concrete Institute.
4. ASTM A 820M-06, "Specification for Steel Fibers for Fiber Reinforced Concrete". ASTM International.
5. Balendran.R.V, Rana T.M., Maqsood T, Tang W.C., "Strength and durability performance of HPC incorporating pozzolans at elevated temperatures", Structural Survey, Vol. 20 ,2002 pp.123 – 128.
6. Brooks, J.J. et al "Effect of admixtures on the setting times of high-strength concrete" Cement Concrete Compos, vol 22, 2000, pp293-301.
7. Caldarone M.A and Gruber K.A , "High Reactivity Metakaolin (HRM) for High Performance Concrete", special publications, vol.153, june1995, pp:815-828.
8. Caldarone, M.A. et al "High reactivity metakaolin: a new generation mineral admixture". Concrete Int, vol.34, November 1994, pp: 37-40.
9. Curcio, F. et al "Metakaolin as a pozzolanic microfiller for high-performance mortars".
10. Ghosh.S, Bhattacharjya S, Chakraborty S "Compressive behavior of Short Fiber Reinforced Concrete", Magazine of Concrete Research, vol.59(8), 2007, pp 567 –574.

## BIOGRAPHY



**CH. RAJ KUMAR** was born in 1992 at Odela Village in Karimnagar district, Telangana. He received his Bachelor of Technology in Civil Engineering from Pathfinder Engineering College, Warangal in 2014. He is currently a final year student of Master of Technology in Structural Engineering from Gurunak Institute of Technology. His research interests cover usage of steel and glass fiber materials in concrete



Assistant Prof. K. Midhunkumar was born in 1992 in Guntur District, Andhra Pradesh. He received his Bachelor of Technology degree in Civil Engineering from JNTUH in 2013. In 2015 he received his Master's Degree in Structural Engineering from JNTUH. He joined Gurunak Institute of Technology as a faculty where he is an Assistant Professor of Civil Engineering Department with a total experience of 2 years in field and education. He is guiding M.Tech Thesis work in field of Structural Engineering.



Prof. S. Madan Mohan received his Bachelor of Technology degree in Civil Engineering from JNTUCE Hyderabad in 1998. In 2001 he received his Master's Degree in Structural Engineering from University College of Engineering Osmania University, Hyderabad. He joined Gurunak Institute of Technology as a faculty where he is a Professor and Head of the Civil Engineering Department with a total experience of 17 years in field of Research, Designing and education.



Dr. S. SREENATHA REDDY Professor & Principal, Guru Nanak Institute of Technology under JNTUH, Hyderabad. Dr. S. SREENATHA REDDY obtained B.Tech, Mechanical Engineering from JNTU, Hyderabad, M.Tech.-Heat power, Refrigeration & Air conditioning from JNTU, Hyderabad and Ph.D. Faculty of Mechanical Engineering from JNTUA. Dr. S. SREENATHA REDDY held various administrative posts and developed the Institution with his projects and developmental activities. Notable among his award i.e National award for best research publication i.e Jawaharlal Nehru memorial prize issued Institution of Engineers on the occasion of Inauguration 27<sup>th</sup> Indian Engineering Congress at New Delhi. He is a young & dynamic Technical Person worked 14 years in Teaching in Mechanical & Aeronautical field and 3 years in Industry from Thermal Power plants. Dr. S. Sreenatha Reddy is having rich experience in administrative area. Earlier he worked as Principal, Head of both the Aeronautical & Mechanical department, coordinating R&D cell for Aeronautical Research and Development Board (ARDB) projects, TPO & developing courseware and implementing ISO 2001 and NBA Accreditation.