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Experimental Study on Confined Concrete with Steel Fiber

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***Abstract*— Steel fibre manufacture has been found to be a brittle material to add the ordinary Portland cement used in concrete and it improves the durability of concrete. The experimental investigationconsisting of casting and testing of compression tests were conducted on 150mm, cube and 150mm x 300mm, cylindrical specimens using a modified test method that gave the complete compressive strength, split tensile test using with and without steel fibre of volume fractions 0,0.5,1,1.5 and 2% of 0.75mm dia of aspect ratio of 80 on ordinary Portland cement concrete.**

As a result the incorporation of steel fibres and cement has produced a strong composite with superior crack resistance, improved tensile strength and behaviour prior to failure. Addition of fibres provided better performance for the cement-based composites; the results predicted by mathematically modelled expressions are in excellent agreement with experimental results. The proposed model was found to have good accuracy in estimating interrelationship at 7days, 14 days and 21 days age of curing.These results indicate that CFRC with proper confinement could be used in structures subjected to extreme load conditions such as seismic loading and impact loading.

I. Introduction

Concrete is a composite material containing hydraulic cement, water, coarseaggregate 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 thecompression 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. Toincrease the tensile strength of concrete many attempts have been made. One ofthe successful and most commonly used method is providing steel reinforcement. Steel bars, however, reinforce concrete against local tension only. Cracks in reinforced concrete members extend freely until encountering are bar. Thus need for multidirectional and closely spaced steel reinforcement arises. That cannot be practically possible. Fibre reinforcement gives the solution for this problem So to increase the tensile strength of concrete a technique of introduction of fibres in concrete is being used. These fibres act as crack arrestors and prevent the propagation of the cracks. These fibres are uniformly distributed and randomly arranged. This concrete is named as fibre reinforced concrete.

The main reasons for adding fibres to concretematrix is to improve the postcrackingresponse of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material.

A. *Advantages of confined steel fibre reinforced concrete*

- Increase split tensile strength
- Increase impact resistance
- Increase abrasion resistance
- Increase toughness
- Increase fatigue resistance
- Increase freeze thaw resistance
- Increase shear strength
- Increase antic rack strength

B. *Need for steel fibre reinforced concrete:*

Fiber reinforced concrete (FRC) is concrete containing fibrous material whichincreases its structural integrity. So we can define fibre reinforced concrete as a composite material of cement concrete or mortar and discontinuous discrete and uniformly dispersed fiber.

Fibre is discrete material having some characteristic properties. The fibre material can be anything. But not all will be effective and economical. Some fibres that are most commonly used are:

- Steel
- Glass
- Carbon
- Natural
- NBD

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

Glass fibre is a recently introduced fibre in fibre concrete. It has very High tensile strength of 1020 to 4080Mpa. Glass fibre 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 fibre 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 fibres is limited. Mainly used for cladding purpose. Natural fibres are low cost and abundant. They are nonhazardousandrenewable. Some of the natural fibres are bamboo, jute, coconut husk, elephantgrass. They can be used in place of asbestos. It increases toughness and flexuralstrength. It alsoinduces 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. TheseNBD materials are noncorrosive, resistant to chemical attack, light in weight,easy to handle. NBD materials – fibre plastic, jute plastic, polythene, disposalglass, cement bags.Studies conducted so far, proved thatthe short and discrete, small fibres canimprove the flexural load carrying capacities and impact resistance for nonferrousfibres.

C. *Scope*

- To reduce cost of the construction
- To promote the low cost structures to the down trodden society.
- To increases moment capacity and cracking moment.
- To increase the ductility.
- To increases crack control.
- To increases rigidity.
- It should be easily adopted in field.

II. EXPERIMENTAL PROGRAM

In order to study the interaction of steel fibres (Hooked end) with concrete under compression, split tension, 45 cubes 45 cylinders were casted respectively. The experimental program was divided into five groups.

Each group consists of 9 cubes, 9 cylinders of 15 x 15 x 15cm, 15cm (dia) x 30cm respectively.

- The first group is the control (Plain) concrete with 0% fibre (PCC)
- The second group consisted of 0.5 % of steel fibres (Hooked end), with aspect cement ratio.
- The third group consisted of 1% of steel fibres (Hooked end), with aspect cement ratio.
- The fourth group consisted of 1.5% of steel fibres (Hooked end) with aspect cement ratio.
- The fifth group consisted of 2% of steel fibres (Hooked end) with aspect cement ratio.

A. *Normal consistency and inital setting time:*

Standard consistency of cement is defined as that water content at which the needle of the apparatus fails to penetrate the specimen by 5mm from bottom of the mould.
Standard Consistency of the cement paste = 30%
Initial Setting Time of cement = 38 min.
Weight of cement taken in the mould = 300 gms.
Needle used: - Plunger size 10mm diameter and 50mm long

WATER CONTENT (%)	DEPTH OF PENETRATION FROM BOTTOM (mm)
28	10
30	5

Consistency of cement = 33%

Table 2.1Normal Consistency

B. *Physical properties of O.P.C*

S.NO	Properties	Test results
1	Specific gravity	3.14
2	Initial Setting Time	38 min
3	Final setting time	560 min
4	Normal consistency	30%

C. *Properties of fine aggregate*

S.no	Properties	Test results
1	Fineness Modulus of fine aggregate	3.67
2	Specific gravity	2.21
3	Bulk density	1.62

D. *Properties of coarse aggregate*

S.no	Properties	Test results
1	Fineness Modulus of coarse aggregate	3.64
2	Specific gravity	2.71
3	Bulk density	1.49

III. FIBRE

A. *HISTORY*

The use of fibres to increase the structural properties of conctruction material is not a new process. From ancient times fibres were being used in construction. In BC, horse hair was used to reinforce mortor. Egyptians used straw in mud bricks to provideadditional strength. Asbestos was used in the concrete in the early 19th century, to protect it from formation of crack. But in the late 19th century, due to increase structural improtance, introduction of steel reinfrocement in concrete was made, by which the concept of fibre reinforced copncrete was over looked for 5-6decades, Later in 1939 the introduction steel replacing asbestos was made for the first time. But at that period it was not successful. From 1960, there was a tremendous development in the FRC, mainly by the introduction of steel fibres. Since then use of different types of fibres in concrete was made. In 1970's principles were developed on the working of the fibre reinforced concrete. Later the decades, codes regarding the FRC are being developed.

B. PROPERTIES OF FIBRE REINFORCED CONCRETE:

Properties of concrete is affected by many factors like properties of cement, fine aggregate, coarse aggregate. Other than this, the fibre reinforced concrete is affected by following factors.

- Type of fibre
- Fibre characteristics
- Aspect ratio
- Quantity of fibre
- Orientation fibre

C. TYPE OF FIBRES

- Steel fibres
- Synthetic organic polymer fibres (polypropylene, nylon,polyester Rayon, polyethylene, cellulose acetate and PVA.)
- Carbon fibres
- Natural fibres
- Asbestos fibres
- Glass fibres

D. FIBRE CHARACTERISTICS

Normally low carbon steel is used for manufacturing steel fibres. The wire strengths of 1000Mpa are achieved by pulling the wires through series of dyes. Corrosion is generally not an issue. The fibres are not interconnected so there can be no corrosion current, hence galvanizing is not recommended.

The are four properties of fibres that are important while selecting fibers as secondary reinforcement in the concrete.

- Fibre geometry-aspect ratio
- Fibre deformation to improve bond
- Physical properties of the steel
- Fibre packaging to simplify mixing.

E. ASPECT RATIO

A numerical parameter describes a quality of fibre is aspect ratio that is fibre length divided by an equivalent fiber diameter. Typical aspect tatio range between 30 to 150mm for length dimension of 0.1 to 7.62cm. Aspect ratio (length/diameter) is a key characteristic in determining performance. High aspect ratios lead to high toughness but without collation fibres tend to ball at aspect ratio over 50. Firer content and its efficiency are the two key variables which controls the performance of fibre reinforced concrete (FRC). In FRC pullout resistance increase with fibre length as pullout resistance is proportional to interfacial area. For a small diameter, the interfacial area would be large enough for bonding. if the aspect ratio is more than the fibre efficiency.

F. FIBRE QUANTITY:

Generally quantity of fibres is measured as percentage of cement content. As the volume of fibres increase, there should be increase in strength and toughness of concrete. Regarding our fibre, we hope that there will be an increase in strength, with increase in fibre content. We are going to test for percentages of 0.5, 1,1.5 and 2.

G. ORIENTATION OF FIBRE:

The orientations of fibres play a key role in determining the capacity of concrete. In RCC the reinforcements are placed in desired direction. But in FRC, the fibres will be oriented in random direction. The FRC will have maximum resistance when fibres are oriented parallel to the load applied.

H. DISPERSION OF STEEL FIBRE IN CONCRETE

One major problem with steel fibre concrete was "Balling". This happen for fibres with aspect ratio of L/D > 50 i.e. high performance fibres added in the concrete quickly. It has also been observed the volume percentage of fibres, types of aggregates intensify balling tendencies. Researchers developed a method where wire form forty spools is fed to a glue line where water dissolvable glue is applied. This phenomenon is known as collation.

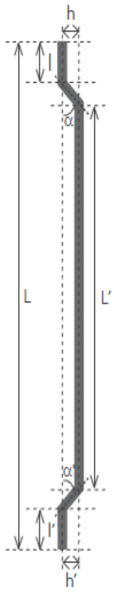
Collation of fibres was a major breakthrough in fibre technology. It is necessary in order to use high aspect ratio fibres without balling. Otherwise for a low aspect ratio<50, loose fibre are recommended. The fibres are packed in such packing, where the entire pack is dissolved with uniform dispersion of fibres.

I. PROPERTIES OF CONCRETE WITH STEEL FIBRES

In addition to improvement of cracking behaviour, steel fibre in concrete increase the dynamic load and fatigue strength Under equivalent stress, withstand greater no. of load cycles than plain concrete, hence we can use a reduced safety factor.

If it is compared with other than polypropylene fibre, it is observed that steel fibre is bettern than PP Fibres in reducing crack width due to restrained drying shrinkage.

PROPERTY	VALUE
Wire diameter (d)	0.75 mm (± 0.04 mm)
Fibre length (L)	60.0 mm (+2/-3 mm)
Hook length (l and l')	1 – 4Hook
Hook depth (h and h')	1.80 mm (+1/-0 mm)
Bending angle (α and α')	45° (min. 30°)
Aspect ratio (L/d)	80
Tensile strength of drawn wire	1200 N/mm^2



Hooked End Fibre of length 60mmand diameter 0.75mm.

J. Workability Tests

- **Slump Cone Test**

Concrete is prepared as per mix design . The freshly prepared concrete is filled in a clean slump cone in four successive layers. 25 tamping is given for each layer properly before adding another layer. Excessive concrete is strike of with trowel from the top of the mould after the final layer has been tamped. The cone is removed immediately by raising it slowly and carefully in the vertical direction. The settlement or subsidence (slump) (i.e. difference between the height of the slump mould and the highest point of the subsidized concrete cone.) in cone measured as soon as it comes to stop.

- **Compaction Factor Test**

Empty weight of the cylinder is noted. The cylinder is fixed at the base of the apparatus. Sample of freshly mixed concrete is filled in the cylinder to the compaction. The excess concrete above the brim of the cylinder is strike off. The cylinder is weighed.

The cylinder is emptied and is refilled with the same mix, filling it in 5 layers with each thoroughly compacted and the cylinder is weighted.

$$\text{Compaction Factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

brim of the upper hopper. The trap door of the upper hopper is released and the concrete is allowed to fall into the lower hopper. Similarly the concrete is allowed to fall into the cylinder producing standard

IV. CONCRETE MIX DESIGN (GRADE –M 25)

The grade of concrete used in the resent study is M25. The following clauses explains briefly about the mix design of the concrete which is carried as per the specific code IS 10262 – 2009.

Characterisitc compressive cube strength at 28 days 25MPa

Maximum nominal size of aggregate : 20mm
Type of aggregate : Crushed angular aggregate
egree of quantity control : Good
Workability : 100mm (Slump min)
Exposure condition : Moderate
(For reinforcement concrete)
Chemical admixture type : Super plasticizer

A. TEST DATA FOR MATERIALS

CEMENT:

Types of cement used : OPC
Specific gravity of cement : 3.15
Maximum cement content : 450 kg/m^3
Minimum cement content : 300 kg/m^3
Maximum W/C ratio : 0.5

1. Specific Gravity

Coarse aggregate = 2.74
Fine aggregate = 2.00
Admixtures = 1.12
Water = 1

2. Water absorption

Coarse aggregate = 0.5 % by mass
Fine aggregate = 1 % by mass

3. Free surface moisture

Coarse aggregate = NIL
Fine aggregate = NIL

4. Sieve analysis

Coarse aggregate : Confirming to table-2 as per (IS -383-1970).
Fine aggregate : Confirming to Zone-II grading of table 4 of (IS 383-1970)

B. DESIGN CALCULATION

1. Calculation of Target mean strengh of concrete
Charactoristic compressive strength fck = 25 N/mm^2
Fck = fck + KS
K = Tolerance factor which not more than 5 % = 1.65
S = Standard deviation (IS 10262-2009)
Table – 1 = 4 N/mm^2
Fck = 25 + 1.65 x 4
= 31.60 N/mm^2
2. Selection of water cement ratio
From table 5 of IS 456-2000 Max. W/C – 0.50
Based on experience adopt W/C ratio - 0.45
0.45 < 0.5 Hence OK.
3. Selection of water content - Table-2
Max. water content for 20mm aggregate = 186 litre
(For 25 – 50mm, slump range for 20mm aggregate)
Estimated water content for 100mm slump
=186 + (186 x (6/100))

= 197 Litre.
As superplasticizer in used the water content can be reduced upto 20% and above based on trials with superplasticizer water content reduction of 21% has been achieved. (100 – 21 = 79%).
Hence arrived water content = 197 x 0.79
Mass of water = 155.63 = 156 litre.

a) Calculation of cement content
Water cement ratio = 0.45
Cement = 156/0.45
=346.66 (or) 347 kg/m^3 > 300 kg/m^3
Hence OK
Calculation of fine aggregate and coarse aggregate:
Table 3 as per IS 10262-2009 Page No. 6
Volume of coarse aggregate=0.62 + 0.02
= 0.64
For pumpable concrete these values should be reduced by 10% by volume based on the trials. (100 – 10 = 90%).
Volume of coarse aggregate =0.64 x 0.90
= 0.58 m^3 by mass
Volume of fine aggregate =1 – 0.58
= 0.42 m^3 by mass

b) Mix Calculations
The mix caluclations as per unit volume of concrete.
Volume of concrete (a) = 1m^3
Volume of cement (b) = (Mass of cement/ Sp. gravity of cement) x (1/1000)
= (34.7/3.15) X (1/1000)
= 0.110 m^3.
Volume of water (c) = (Mass of water/ Sp. gravity of water) x (1/1000)
= (156/1) x (1/1000)
= 0.156 m^3.
Volume of chemical admixtures superplasticizer (d)= (Mass of chemical admixtures/Sp. gravity of admixture) x (1/1000)
= (4.161/1.12) x (1/1000)
= 0.0037 m^3.
Volume of all in aggregate = a – (a + c + d)
= 1 – (0.110 + 0.156 + 0.0037)
=0.7303 m^3.
Mass of coarse aggregate = Volume of all in concrete x Vol. of coarse aggr.x Sp. gravity of coarse aggregate x 1000
= 0.7303 x 0.58 x 2.74 x 1000
= 1160.59 kg/m^3.
There fore Mass of coarse aggregate = 1161 kg/m^3.
Mass of fine aggregate=Vol. of agg .x Vol. of fine agg. x Sp. gra. fine agg. x 1000
= 0.7303 x 0.42 x 2.74 x 1000
= 800.4 kg/m^3.= 840 kg/m^3.
Mix proportion: **1 : 2.47 : 3.35**

Cement	Fine aggregate	Coarse aggregate	Water
347	840	1161	156
1	2.47	3.35	0.45

Volume Calculations:
Volume of one cube = 0.15 x 0.15 x 0.15
= 3.375 x 10^{-3} m^3
Volume of cylinder= (π x 0.15^2 / 4) x 0.3
= 5.30 x 10^{-3}
Total Volume to be filled with concrete
= 8.675 x 10^{-3} m^3

Quantity Calculations:
Cement required =8.675 x 10^{-3} x 347= 3.01 kg
Fine aggregate =8.675 x 10^{-3} x 840= 7.287 kg
Coarse aggregate =8.675 x 10^{-3} x 1161= 10.07 kg
Water required =0.45 x 3.01 = 1.35 lit.

6. EXPERIMENTAL PROGRAM

In order to study the interaction of steel fibres (Hooked end) with concrete under compression, split tension, 45 cubes 45 cylinders were casted respectively. The experimental program was divided into five groups.

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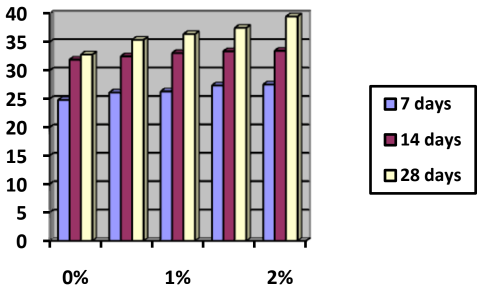
The specimens were designed and detailed as per IS 456:2000 and detailed as per IS 13920:1993.

V. RESULT AND DISCUSSION

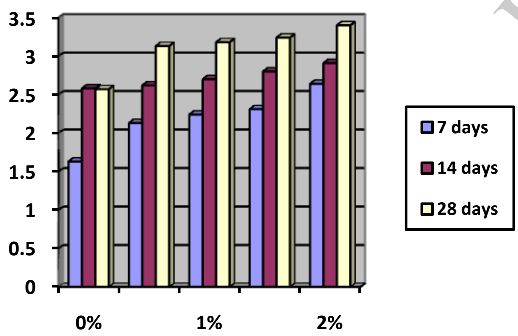
a) Test Result for compressive strength

S.No.	Percentage of Fibres (%)	CompressiveStrength (N/mm^2)		
		7 days	14 days	28 days
1	**0**	**24.80**	31.9	32.8
2	**0.5**	**26.12**	32.5	35.4
3	**1**	**26.31**	33.07	36.4
4	**1.5**	**27.36**	33.39	37.5
5	**2**	**27.53**	33.47	39.5



Test Result for split tensile strength

S.No.	Percentage of Fibres (%)	Split tensile strength (N/mm^2)		
		7 days	14 days	28 days
1	**0%**	**1.63**	**2.58**	**2.57**
2	**0.5%**	**2.03**	**2.62**	**3.13**
3	**1%**	**2.24**	**2.70**	**3.18**
4	**1.5%**	**2.31**	**2.80**	**3.24**
5	**2%**	**2.64**	**2.91**	**3.40**



VI. DISCUSSIONS AND COMPARISION

Compressive Strength and Split Tensile strength:

The variation in the compressive stress and split tensile stress with respect to changes in the fibre content can be observed. From the results obtained, it is clear that the compressive and split tensile strength of concrete is maximum when the fibre content is 2 % of the concrete. So comparing the variation of strength between the plain concrete and fibre reinforced concrete (2%).

Comparing the compressive strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Plain Concrete (N/mm^2)	SFRC (N/mm^2)	Percentage Increase in strength
0% : 32.8	0.5% : 35.4	7.92%
	1% :36.4	10.97%
	1.5% :37.5	14.32%
	2% : 39.5	20.42%

Comparing the split tensile strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Plain Concrete (N/mm2)	SFRC (N/mm2)	Percentage Increase in strength
0% : 2.57	0.5% : 3.13	21.7%
	1% : 3.18	23.7%
	1.5% : 3.24	26.1%
	2% : 3.40	32.2%

From the table it is clear that the strength of SFRC with 2% fibre has increased by 14 days test 4.92% and 28 days test 20.42% for compression.and 14 days test 12.7% and 28 days test 32.2 % under split tensioncompared to the plain concrete.

VII. CONCLUSIONS

- The steel fibres (hooked end) used in this project has shown considerable improvement in all the properties of concrete when compared to conventional concrete like.

i) Compressive strength by 20.42 % for 2% of steel fibre.

ii) Split Tensile strength by 32.2 % for 2% of steel fibre

- The steel fibres are free from water absorption. With improved understanding of the link between fibre characteristics and composite or structural performance , the tailoring of fibres for use in high volume construction market exists, particularly for load carrying structural systems and for several applications especially in earthquake and in Earthquake prone areas. The time is not far that such materials will be used in building better and safe constructions for the future.

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