Comparative study of Fiber Reinforced Concrete

Mr.Jeet Shinde, Mr.Shubham Ahire, Mr.Nikhil Mane, Mr.Rohit Rathod, Mr.Abhishek Shinde.
Department of Civil Engineering
JSPM Narhe Technical Campus, Pune.

ABSTRACT
The inclusion of fiber reinforcement in concrete, mortar and cement paste can enhance many of the engineering properties of the basic materials, such as fracture toughness, flexural strength and Impact. In this examination, the general properties of the composites are described in relation to fiber content, length, and strength. A chronological development of steel and sisal fiber reinforced, cement-based matrices are reported and experimental data are provided to illustrate the performance of steel and sisal fiber reinforced cement composites. The results shows that the composites reinforced with steel and sisal fibers are reliable materials to be used in practice for the production of structural elements, which is to be used in rural and civil construction. This material could be a substitute for asbestos-cement composite, which is a serious hazard to human and animal health and is prohibited in industrialized countries. In this research, the various tests like Compressive strength and Flexural strength of Steel Fiber Reinforced Concrete and Sisal Fiber Reinforced Concrete (SFRC) are carried out for 7 and 28 days and cured at room temperature. In this investigation fibers of 5 cm length are used. We conducted above mentioned tests on specimens for steel and sisal fiber like 1%.

Key words: composite material, natural fibers, concrete, mortar, compressive strength, flexural strength.

INTRODUCTION

The behavior of fiber reinforced concrete (FRC) composites subjected to combined static loads and to impact, dynamic, and blast loads has been studied by researchers in India for quite some time. Work is under way too on the development of polymer-impregnated fiber reinforced concrete and fibrous ferroconcrete, with which precast concrete components can be produced to meet specific functional and strength requirements. A great deal of work has also been carried out in developing precast roofing units, particularly for housing, using natural fibers. This paper describes some of these current research efforts and applications for FRC composites in India

In conventional concrete, micro-cracks develop before structure is loaded because of drying shrinkage and other causes of volume change. When the structure is loaded, the micro cracks open up and propagate because of development of such micro-cracks, results in inelastic deformation in concrete. Fiber reinforced concrete (FRC) is cementing concrete reinforced mixture with more or less randomly distributed small fibers. In the FRC, a number of small fibers are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all directions. The fibers help to transfer load to the internal micro cracks. FRC is cement based composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural-tensile strength, resistance to spitting, impact resistance and excellent permeability and frost resistance. It is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. These fibers have many benefits. Steel fibers can improve the structural strength to reduce in the heavy steel reinforcement requirement. Freeze thaw resistance of the concrete is improved. Durability of the concrete is improved to reduce in the crack widths. Many developments have been made in the fiber reinforced concrete.

Concrete made from Portland cement, is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bars reinforcement and to some extent by the mixing of a sufficient volume of certain fibers. The use of fibers also recalibrates the behavior of the fiber-matrix composite after it has cracked through improving its toughness (Nataraja M.C., Dhang N). This thesis is aims to provide information on the properties and applications of the more commonly available fibers and their uses to produce concrete with certain characteristics.

Fiber Reinforces Concrete

A new kind of fiber reinforced concrete is developed which is made from cellulose fibers. A fiber is a small discrete reinforcing material produced from various materials like steel, plastic, glass, carbon and natural materials in various shapes and size.

A numerical parameter describing a fiber as its aspect ratio, which is defined as the fiber length, divided by an equivalent fiber diameter.

Typical aspect ratio[l/d] range from 30 to 150 for length dimensions of 0.1 to 7.62 cm typical fiber diameters are 0.25 to 0.76 mm for steel and 0.02 to 0.5 mm for plastic.

The plain concrete fails suddenly when the deflection corresponding to the ultimate flexural strength is exceeded, on the other hand fiber reinforced concrete continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete.

Characteristics of Sisal Fibers:

Sisal fiber is a one of the cellulosic fibers. It contains cellulose around 70% in the fiber. With cellulose, this fiber also consists of hemicelluloses, lignin, pectin and wax etc. the properties of this fiber are greatly affected by its chemical composition. In a cellulose fiber, the cellulose is the strongest organic component which gives the fibers with strength, stiffness and stability, here, sisal fiber contains 70 % only by cellulose. Hence, we can say that sisal fiber is a one of the strongest fibers. Hemicelluloses are polysaccharide bonded together in relatively short, branching chains. Lignin is a complex aromatic hydrocarbon polymer that imparts rigidity to plants. The proportion of various ingredients in the sisal fiber is presented in tabular forms as shown following:

Chemical compositions of Sisal fibers.

Ingredients	**Content (%)**
Cellulose	71.5%
Hemicelluloses	18.12%
Lignin	5.90%
Pectin	2.3%
Fats	0.5%
Water soluble matter	1.7%

Physical and Mechanical Properties of Sisal fibers:

The mechanical properties of fibers also depend on the physical properties of these fibers such as fiber diameter, length, density etc. Table 2 shows various physical and mechanical properties of sisal fibers. Sisal fibers were obtained from a local supplier named Chandra Prakash and company from Jaipur-India. Sisal fiber is completely biodegradable, green composites were made-up with soy protein resin modified with gelatin. The Physical and Mechanical properties of the sisal fiber are presented in tabular forms as shown following:

Physical & Mechanical properties of Sisal fibers.

Description	Sisal Fibers
Diameter (mm)	0.20 (Varies)
Length (mm)	1200 (Varies)
Apparent specific gravity.	0.69
Moisture content (%)	11.00
Water absorption (%)	65.00
Tensile strength (MPa)	350
Modulus of elasticity (GPa)	13.99

Properties of Steel Fibres:

Steel fibres are discrete, short in length, round in shape, aspect ratio from 20 to 100, diameter from 0.25 to 0.75mm which are dispersed in the concrete during the mixing process.

Steel fibres are bundled together with the help of water-soluble glue which further separated during the mixing process of the concrete.

The typical properties of the steel fibres are, tensile strength of 280 to 420 Map, poison's ratio is 0.30, young's modulus of 200 GPa, ultimate elongation of 3.6 %, specific gravity of 7.86.

The manufacturing technique for the steel fibres is cut wire/ cold drawn. the product should be purchased as per the application. steel fibres are available in the shape of round, rectangular (0.3 to 0.5 mm thick), also available in deformed bundled form.

The shorter length fibres are used to control the cracking while longer length fibres are used to gain high anchorage between fibres and concrete. The mix design can be done according to the purpose of use.

Physical properties of Steel fibers.

1. Fiber type	Hooked steel fibers
2. Fiber length	50mm
3. Tensile strength	1100 N/mm2
4. Young's modulus	$2x10^5$ MPa
5. Density	7800 kg/m3
6. Aspect ratio	67
7. Diameter	0.75mm

LITERATURE WORK

1. **May 2021| IJIRT:** In this paper concentrate about the behavior of concrete when ground nutshell ash and rice husk ash and sisal fibers are added in concrete and using the mix design of M30 grade. G.S.A & R.H.A are added in concrete of 2.5%, 5%, 7.5% and 10%, sisal fibers are 2% constant. In this investigation compressive and split tensile strength of concrete specimens are given optimum results with 2.5% replacement of cement by G.S.A & R.H.A at 7 days and 28days.finally the achieved compressive strength and split tensile strength was more in G.S.A than compared R.H.A

2. Majid Ali: He studied the mechanical and dynamic properties of coconut fiber reinforced concrete (CFRC). He investigated then the mix proportions of 2%, 3% and 5% fiber contents by mass of cement and fiber lengths of 2.5, 5 and 7.5 cm is investigated. Noor Md. Sadiqul Hasan, etc. They have investigated the physical and mechanical characteristics of concrete after adding coconut fiber on a volume basis.

3. Jianqiang Wei, Christian Meyer (October 2013) Studied Improving degradation resistance of sisal fibre in concrete through fibre surface treatment. In her experiment she explained Concrete specimens were subjected to cycles of wetting and drying to accelerate aging. The microstructure, tensile strength and Young's modulus of sisal fibre as well as the weight loss of the composite were evaluated.

4. Prof. Yogesh Suryawanshi, Mr. Jiendra Dalvi (March2013) Studied the use of Sisal Fibre as reinforcement In Cement Based Composites. In their Work they explained inclusion of fibre reinforcement in concrete, mortar and cement paste can enhance many of the engineering properties of the basic materials, such as fracture toughness, flexural strength and resistance to fatigue, impact, thermal shock and spalling.

5. **Dr. B. Jayarami Reddy(2022):** With improved understanding of the link between Fiber characteristics and composite or structural performance, the tailoring of Fibers for use in high volume construction market exists, particularly for load carrying structural systems and for several applications especially in Earthquake prone areas. The time is not far that such materials will be used in building better and safe constructions for the future.

6. Mr. Nikhil A. Ghadge, Prof.S.S.Vidhale (December 2013) Studied the Mix Design of Fibre Reinforced Concrete using Slag and Steel Fibre. In his work they focus on the Compressive Strength performance on blended concrete containing different percentage of slag steel fibre as partial replacement of OPC. The cement in in the concrete is replaced accordingly with the percentage of 10%, 20%, 30% and 40% by weight of slag and 0.5%, 1%, 1.5% and 2% by weight of steel fibre

7. **Agave Sisalana (2022)**: Based on the results of our investigation, the following conclusions were Arrived using the natural sisal fiber lincrease the strength of concrete. The optimum percentage of sisal fiber for maximum strength was 1% for compressive strength and split tensile strength. Workability decreases with increase in percentage of sisal fiber replaced with o.5%.1.0%,1.5% of weigth of cement. Sisal fiber is treated with NA2CO3 proportion.The recommended optimum mix based on the physical and mechanical parameters In this study is 1% sisal fiber addition, which gave 38.12 N/mm^2 compressive Strength.

Methodology

Materials Used:

Cement:

The cement is called Portland slag cement because of that Blast- furnace slag may also be used in some cements and the color of the cement due chiefly to iron oxide. In the absence of impurities, the color would be white, but neither the color nor the specific gravity is a test of quality. Ordinary Portland cement 53 grade (Ultratech Cement) was use, the specific gravity is 3.15.

Coarse Aggregate:

Normal aggregate that is crushed blue granite of maximum size 20 mm was used as coarse aggregate. We are conducting tests on coarse aggregate are Water Absorption Capacity, Specific Gravity, Impact Value and of coarse aggregate. The many aggregate properties that are very important with respect to concrete strength are particle size distribution, shape of the particles, mechanical properties of the aggregate properties, and different types of chemical reaction between the aggregate and the cement- paste which may have an effect on the bond. So, the grading of aggregates should be very carefully controlled, so that good mixing and workability property can be achieved.

Fine Aggregate:

Normal aggregate that is crushed blue granite of maximum size 10 mm was used as fine aggregate. We are conducting tests on coarse aggregate are Water

Absorption Capacity, Specific Gravity, Impact Value of fine aggregate.

Crushed Sand:
We used well graded crushed sand passing through 4.75 mm was used as fine aggregate. The sand was air-dried and sieved to remove any foreign particles prior to mixing. We are conducting tests on fine aggregate are silt content, sieve analysis & Specific Gravity. The sand particles or fine aggregates should also pack to give minimum void ratio, higher voids content leads to impurities. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. To coat the large surface area of the fibers with paste, experience indicated that a water requirements of more mixing water. To reduce the water demand, the fine aggregates used should have smooth rounded particles. In the present study the sand confirms to Zone III as per Indian standards (IS: 10262-2009 and IS: 383-1970).

Water:
Water available conforming to the requirements of water for concreting and curing as per IS: 456-2000. Water to be used for concreting should be free from

cement ratio between 0.4 and 0.6, and minimum cement content of 320 kg/m³ are required.

Fibers:
Typically, the fibers are added in the mix, just after all concrete aggregates are being mixed.

Number of Cubes and Beams to be Casted:

Percentage of Fibers used for Casting = 1%
Size of Cube = 150mm x 150mm x 150mm
Size of Beam = 150mm x 150mm x 700mm

Number of Cubes and Beam to be Casted.

1%	**Steel FRC**		**Sisal FRC**	
Tests	7 Days	28 Days	7 Days	28 Days
Compression Testing	3	3	3	3
Flexure Testing	3	3	3	3
Total Cubes	**24**			

Specific Gravity and Water Absorption of Coarse Aggregate

A. Size 20mm

Sr. No.	Details	Trial-1	Trial-2
1	Wt. of Aggregate in SSD Condition	800	800
2	Wt. of Pycnometer + Sample + Water (B)	2088	2091
3	Wt. of Pycnometer + Water (C)	1561	1560
4	Wt. of Dry sample (D)	797	798
5	**Specific Gravity = D/ [A – (B - C)]**	2.92	2.97
	Average	**2.94**	
6	**Water Absorption = (A - D)/D X 100**	0.38	0.25
	Average	**0.31**	

Specific Gravity and Water
Absorption of Coarse Aggregate.

A. Size 10mm

Sr. No.	Details	Trial-1	Trial-2
1	Wt. of Aggregate in SSD Condition	800	800
2	Wt. of Pycnometer + Sample + Water (B)	2098	2084
3	Wt. of Pycnometer + Water ©	1561	1558
4	Wt. of Dry sample (D)	783	786
5	**Specific Gravity = D/ [A – (B – C)]**	2.98	2.87
	Average	**2.92**	
6	**Water Absorption = (A - D)/D X 100**	2.17	1.78
	Average	**1.98**	

Specific Gravity of Fine Aggregate

	Details	Trial-1	Trial-2
1	Wt. of Aggregate in SSD Condition	500	500
2	Wt. of Pycnometer + Sample + Water (B)	1869	1872
3	Wt. of Pycnometer + Water (C)	1560	1560
4	Wt. of Dry sample (D)	495	495
5	**Specific Gravity = D/ [A – (B - C)]**	2.59	2.63
Average		**2.61**	
6	**Water Absorption = (A - D)/D X 100**	1.01	1.01
	Average	**1.01**	

Impact Value Test

Sr. No	Details	Trial - 1	Trial - 2	Average
1	Total Weight of Oven dried sample (W1) gm	348	351	**15.74**
2	Weight of material retained on 2.36mm after testing (W2) gm	308	302	
3	Weight of material passing on 2.36mm after testing (W3) gm	56	54	
4	Avg. Impact Value (%) = (W3/W1)*100	16.09	15.38	

<u>Testing data of Materials:</u>

Results of material testing

1. Specific gravity test on fine aggregates	2.61
2. Specific gravity test on coarse aggregates	2.94
3. Water absorption test on fine aggregates	1.01 percent
4. Water absorption test on coarse aggregates	0.31 percent
5. Specific gravity test on cement	3.15g/cm^3
6. Aggregate Impact Value Testing	15.74 %

Mix Proportion for M25 Grade:

Mix Proportion for M25

	Grade M25	Kg/Cum	For Compression	For Flexure
1)	Volumes		0.0405	0.189
2)	Cement	505	20.45	95.45
3)	Reduce 1% (For Fiber)	5.05	0.20	0.95
4)	Net Cement	499.95	20.25	94.49
5)	water	235	**9.52**	**44.42**
6)	Coarse Aggregate			
	20 mm	640.52	**25.94**	**121.06**
	10 mm	519.61	**21.04**	**98.21**
7)	Fine Aggregate			
	Crushed Sand	627.39	**25.41**	**118.58**
8)	Admixture	-	-	-
9)	**Fiber Sisal (gm) 1 cube**		**102.26**	**477.23**
10)	**Fiber Steel (gm) 1 Cube**		**102.26**	**477.23**

Results And Discussions

Cube (150 x 150 x 150) mm:

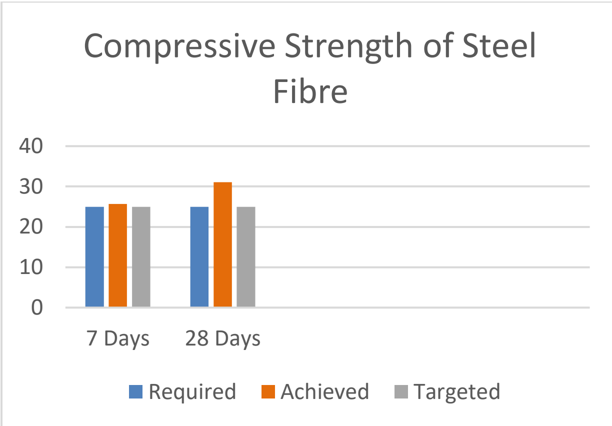
The following table shows the compressive strength of Sisa Fiber Reinforced Concrete and Steel Fiber Reinforced Concrete cubes where the steel fiber and sisal fiber of percentage 1% is replaced with weight of cement for 7 days and 28 days.

Compressive Strength of Cube for 1% Sisal Fibers

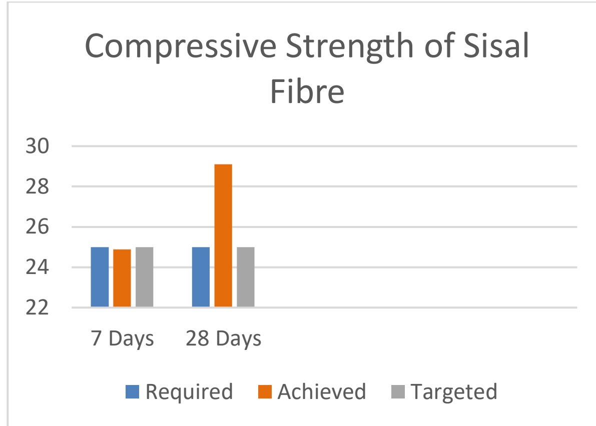
Sr. No.	Age (Days)	Weight of Cubes (gm)	Compressive Load (KN)	Compressive Strength (N/mm^2)	Avg. compressive strength (N/mm^2)
1	7	8945	560.2	24.89	24.89
2		8910	554.8	24.6	
3		8905	567.5	25.2	
1	28	8940	657.9	29.24	29.10
2		9010	648.6	28.82	
3		8920	652.2	28.98	

Compressive Strength of Cube for 1% Steel Fibers

Sr. No.	Age (Days)	Weight of Cubes (gm)	Compressive Load (KN)	Compressive Strength (N/mm^2)	Avg. compressive strength (N/mm^2)
1	7	8945	578.9	25.76	25.65
2		8910	565.3	25.12	
3		8920	586.3	26.08	
1	28	8945	697.9	31.01	31.03
2		8920	695.2	30.89	
3		9010	702.5	31.20	



Compressive Strength of Sisal fiber for 7-days and 28-days



Compressive Strength of Steel fiber for 7-days and 28-days

Beam (150 x 150 x 700) mm:

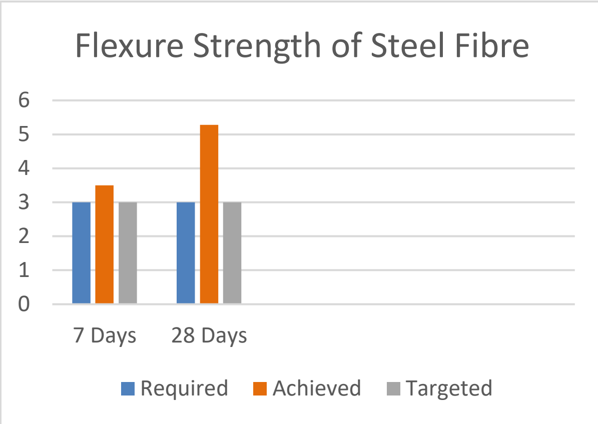
The following table shows the compressive strength of Sisa Fiber Reinforced Concrete and Steel Fiber Reinforced Concrete cubes where the steel fiber and sisal fiber of percentage 1% is replaced with weight of cement for 7 days and 28 days.

Flexure Strength of Cube for 1% Sisal Fibers

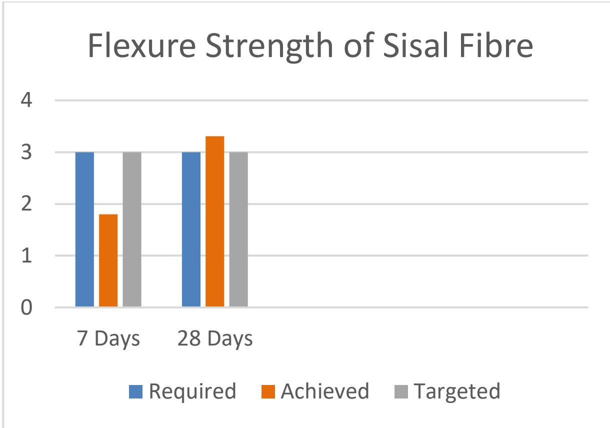
Sr. No.	Age (Days)	Weight of Cubes (gm)	Flexure Load (KN)	Flexure Strength (N/mm^2)	Avg. compressive strength (N/mm^2)
1	7	40231	14.63	1.29	1.8
2		40220	18.72	1.89	
3		40225	17.86	2.32	
1	28	40253	30.20	3.20	3.31
2		40213	31.06	3.45	
3		40236	30.40	3.28	

Cube for 1% Steel Fibers

Sr. No.	Age (Days)	Weight of Cubes (gm)	Flexure Load (KN)	Flexure Strength (N/mm^2)	Avg. compressive strength (N/mm^2)
1	7	40220	33.49	3.23	3.5
2		40231	35.61	3.53	
3		40212	37.60	3.8	
1	28	40236	57.97	5.49	5.38
2		40226	52.89	5.34	
3		40224	53.47	5.30	



Flexure Strength of Steel fiber for 7-days and 28-days



Flexure Strength of Sisal fiber for 7-days and 28-days

CONCLUSION

From the experimental work, result and discussion, various concluding points are summarized:

From the slump values it is concluded that the amount of water required to obtain required workability is higher for fiber concrete. The workability of fiber reinforced concrete is lesser than normal concrete for same water content. It indirectly gives that compaction of concrete is difficult as increase fiber content.

The Sisal fiber shows **small improvement** in compressive strength when compares to normal concrete for 1%. After that the difference of compressive strength between concrete with sisal fiber and without sisal fiber decreases with the increase of curing period. Therefore, based on the obtained results, Sisal fiber reinforced concrete is suitable for compressive strength purpose.

The Steel fiber shows **great improvement** in compressive strength when compares to normal concrete for 1%. After that the difference of compressive strength between concrete with steel fiber and without sisal fiber decreases with the increase of curing period. Therefore, based on the obtained results, Sisal fiber reinforced concrete is suitable for compressive strength purpose.

The flexural strength is improved with addition of steel and sisal fiber. The percentage increments in flexural strength with steel and sisal fiber percentage are 1% with compare to normal concrete. It can also be concluded that the flexural strength of sisal fiber reinforced concrete is significantly improved as compare to normal concrete.

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