

An Experimental Study on Mechanical and Durability Properties of Concrete Made with Natural and Artificial Fiber

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Abstract

The basic objectives behind using of fibers are to reduce cracking in concrete and to increase its strength. This experimental work was carried out to evaluate mechanical and durability properties of concrete made of 1% sisal fiber and 1% steel fiber for M20 grade concrete. Mechanical properties were studied by performing compression test (150mm×150mm size cubes), split tensile test (150mm diameter and 300mm length cylinders) and durability properties were studied by performing acid attack test (150mm×150mm size cubes). Various tests like Compression test and Split tensile test were performed on concrete cubes and concrete cylinders. It was observed that the strength and durability parameters were enhanced by using these fibers.

Keywords: Concrete, Sisal fiber, Steel fiber, Compressive strength, Split tensile strength

I. INTRODUCTION

Concrete is a versatile material possessing good compressive strength but it undergoes from many obstacles like low tensile strength permeability to liquids, corrosion of reinforcement, susceptibility to chemical attack and low durability. In conventional concrete, micro-cracks develop even before loading because of drying shrinkage and other cause of volume change. When the structure is loaded, the micro cracks get exposed and propagate. The growth of such micro-cracks is the chief cause of inelastic deformation in concrete. This is due to concrete's brittle character, and can be partially eliminated by using fibers which introduces tensile and ductile properties into concrete. The addition of fibers in concrete substantially improve its static and dynamic properties. this fibers offer increased resistance to crack growth, through a crack arresting mechanism and improve tensile strength and ductility of concrete. The inclusion of fibers in concrete generally improves material properties like ductility, flexural strength, toughness impact resistance and fatigue strength. The type and amount of improvement is dependent upon the fiber type, size, strength and configuration and amount of fiber. As stated in ACI 544, 3R-08[2], fiber volume fraction used in producing steel fiber reinforced concrete should be in between 0.5% to 1.5% because further addition of fiber will lead to reduction in the workability of the mix. Aspect ratio is referred to the ratio of fiber length over the diameter. The normal range of aspect ratio for steel fiber and sisal fiber is from 20 to 100. With modernization in concrete technology fiber reinforced concrete is already being used in large scale construction projects involving construction works like pavements, industrial floors, highways-overlays etc.

II. FIBER REINFORCED CONCRETE (FRC)

Fibers have been used as reinforcement from primitive time. Fiber reinforced concrete can be defined as composite material consisting of concrete and discontinuous, discrete, uniform dispersed fine fibers. The continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers. Fiber reinforced concrete is one of the fastest growing segments in the concrete industry as more and more engineers, architects, owners, specifiers and concrete contactors are turning to the use of fibers to supply their reinforcing needs in their concrete applications.

The current Experimental Exploration is to survey Mechanical Properties and Durability properties of concrete with addition of little percentage by weight of Sisal and Steel fibers.

A. Material and Properties

1) Cement

The cement used in this experimental effort is Ultratech 53 grade Ordinary Portland Cement. The specific gravity of this cement is 3.15. Standard consistency of cement was 31.5%. All properties of cement are tested by referring IS 12269 – 1987.

2) Sisal Fiber

Botanical name of sisal is called *Agave sisalana*, is a type of *Agave* inhabitant to southern part of Mexico but it is also widely grown in various countries today. It produces a robust fiber used in manufacturing different types of products. Conventionally, sisal has been the primary material for agricultural twine (binder twine and baler twine) because of its strength, ability to stretch, durability, and resistance to corrosion in saltwater.



Fig. 1: Sisal Fiber

Table - I
Properties of Sisal Fiber

<i>Sr.No</i>	<i>Physical Property</i>	<i>Test Results</i>
1	<i>Length(mm)</i>	60
2	<i>Diameter(mm)</i>	1

The sisal fibers are used as shown in Fig.1 and properties of the same is given in Table I. Addition of sisal fiber to a plain matrix has negligible effect on its pre cracking behavior but does enhance its post cracking behavior.

3) Fine Aggregates

Domestically available sand of Bodeli is used in this research. Sand passing from 4.75 mm sieve and of specific gravity of 2.63 and fineness modulus of 2.84 are used.

4) Coarse Aggregates

Aggregate of size 20 mm and 10 mm available from the domestic site Sevalia are used. Specific gravity of course aggregate is 2.77 and fineness modulus is 6.59.

5) Water

Fresh potable water free from acid and organic substances was used for mixing and curing concrete

6) Steel Fiber

It is well recognized that one of the significant properties of steel fiber reinforced concrete (SFRC) is its superior conflict to cracking and crack propagation. As a result of this talent to capture cracks, fiber composites hold improved extensibility and tensile strength, both at leading crack and at decisive, and the fibers are able to clamp the substance together even after wide cracking. The final result of all these is to impart to the fiber multipart definite post – cracking ductility which is ignored of in control concrete. The revolution from a brittle to a ductile type of material would increase greatly the energy absorption characteristics of the fiber and its ability to withstand constantly applied, impact or shock loading. Fig.2 shows steel fibers used in this study with properties as shown in Table II.



Fig. 2: Steel Fiber

Table - II
Properties of Steel Fiber

<i>Sr.No</i>	<i>Physical Property</i>	<i>Test Results</i>
1	<i>Length(mm)</i>	30
2	<i>Diameter(mm)</i>	0.50

B. Experimental Work

1) Mix Proportion

The mix proportion shown in Table III was made for a concrete with a slump 100mm and M20 grade as per method given by IS: 10262 – 2009.

Table – III
Mix Proportion

<i>Material</i>	<i>Weight (Kg/m3)</i>
<i>Cement</i>	320
<i>Water</i>	138
<i>Fine aggregate</i>	751
<i>Coarse aggregate</i>	1356
<i>W/C ratio</i>	0.45

2) Casting and Curing

Casting was done as per combinations shown in Table IV

Table – IV
Design of Mix

<i>Concrete</i>	<i>%addition of fiber</i>
<i>Control</i>	0%
<i>Sisal fiber concrete</i>	1%
<i>Steel fiberConcrete</i>	1%

Mixing of ingredients was done as per IS 516 (1959) by hand mixing. The concrete was first filled in layers of 5cm and compacted by table vibratos. The specimens were removed after 24 hours and submerged in water and have been left curing. After a curing period of 7 and 28 days specimens were taken out and tested.

C. Testing

Specimens were tested to find out mechanical properties at 7 and 28 days by performing following tests:

1) Compression Test

Compression test on cubes of size 150mm was performed on compression testing machine as shown in Fig.3. Average compressive strength of three cubes was taken after 7 and 28 days.

2) Split Tensile Test

Split tensile test as shown in Fig.5 was performed on cylinders 150mm dia. and 300mm height on compression testing machine as per the method given in IS: 5816 – 1999. The failure load was recorded to find out split tensile strength.

To study the durability properties, following test was performed :

3) *Acid Attack Test*

Solution of 5% HCL by volume was prepared as shown in Fig.8 and cubes of size 150×150×150mm were immersed in solution after 28 days normal curing after taking initial weights. The cubes were weighted and tested on compression testing machine after 7 and 28 days.

III. RESULTS AND DISCUSSION

A. Compressive Strength



Fig. 3: Compression Test

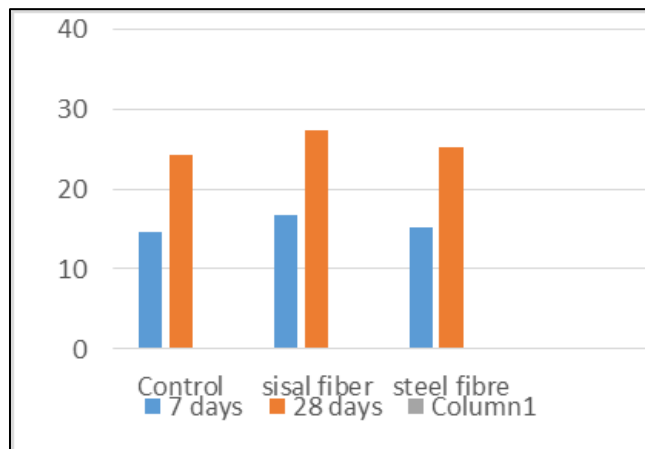


Fig. 4: Compressive Strength

The results of compressive strength are shown in Fig. 4.

Table - IV

Result of compressive strength for M20 Grade Concrete

Type of block	Percentage of fiber added	strength after 7 days (KN)	strength after 28 days (KN)
Control	-	14.6	24.3
Sisal fiber	1%	16.8	27.4
Steel fiber	1%	15.2	25.2

As shown in Table IV, percentage increase in compressive strength of sisal fiber compared to control concrete after 7 days is 15.06% and increase in compressive strength of steel fiber compared to control concrete after 7 days is 4.10%. After 28 days, percentage increase in compressive strength of sisal fiber and steel fiber compared to control concrete are 12.75% and 3.70% respectively. Percentage increase in compressive strength of sisal fiber compared to steel fiber after 7 days and 28 days are 10.52% and 8.73% respectively.

B. Split Tensile Strength

The results of split tensile strength of concrete are shown in Fig 6.



Fig. 5: Split Tensile Test

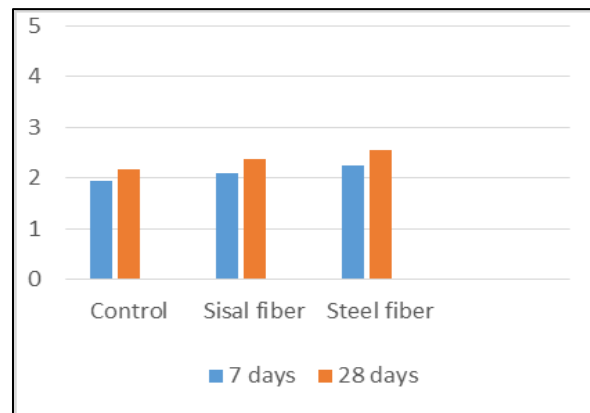


Fig. 6: Split Tensile Strength

Table - V
Result of tensile strength for M20

Type of block	Percentage of fiber added	strength after 7 days (KN)	strength after 28 days (KN)
Control	-	1.95	2.17
Sisal fiber	1%	2.09	2.39
Steel fiber	1%	2.26	2.56

As shown in Table V, % increase in tensile strength of sisal fiber compared to control concrete after 7 days is 7.17% and increase in tensile strength of steel fiber compared to control concrete after 7 days is 15.89%. After 28 days, percentage increase in tensile strength of sisal fiber and steel fiber compared to control concrete are 10.13% and 17.97% respectively. Percentage increase in tensile strength of steel fiber compared to sisal fiber after 7 days and 28 days are 8.13% and 7.11% respectively.

C. Acid Attack Test

Fig.7 Shows percentage reduction in mass and Fig 4. Shows percentage reduction in strength.

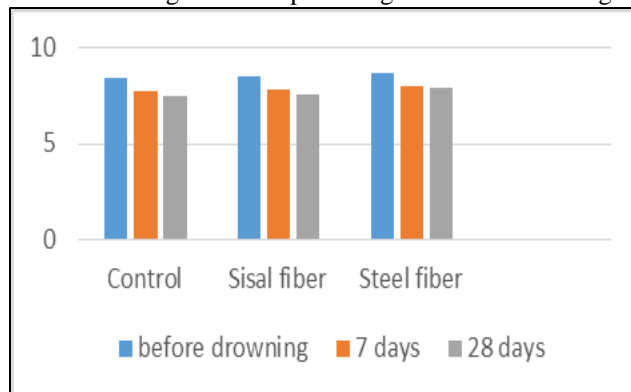


Fig. 7: % loss of mass in acid

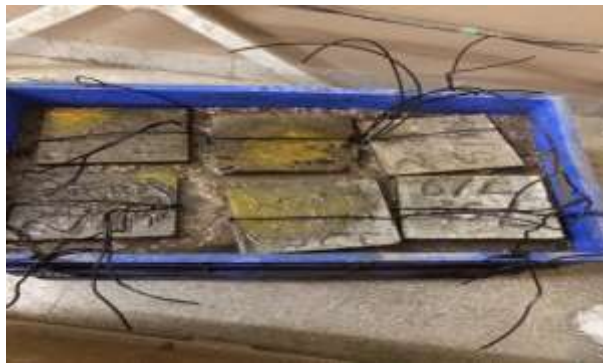


Fig. 8: Acid Attack Test

Table - VI
Result of acid attack test on weight of cubes

Type of block	Weight of concrete block before drowning into acid (in Kilogram)	Weight of concrete block 7 days after drowning into acid (in kilogram)	Weight of concrete block 28 days after drowning into acid (in kilogram)
Control	8.45	7.78	7.55
Sisal fiber	8.58	7.89	7.61
Steel fiber	8.73	8.03	7.93

As per table VI, due to acid attack test percentage loss in weight of control concrete block after 7 days is 7.92% and after 28 days percentage loss in weight of control concrete block is 13.24%. In the case of sisal fiber concrete percentage loss in weight after 7 days & 28 days are 8.04% and 11.30% respectively. In the situation of steel fiber concrete percentage decrease in weight after 7 days and 28 days are 8.01% and 9.16% respectively.

In comparison with control concrete loss of weight in sisal fiber concrete due to acid attack test at 7 days is 1.41% less and at 28 days it is 0.79% less. In steel fiber concrete, loss of weight compared to control concrete at 7 days is 3.21% lesser and at 28 days it is 0.50% less.

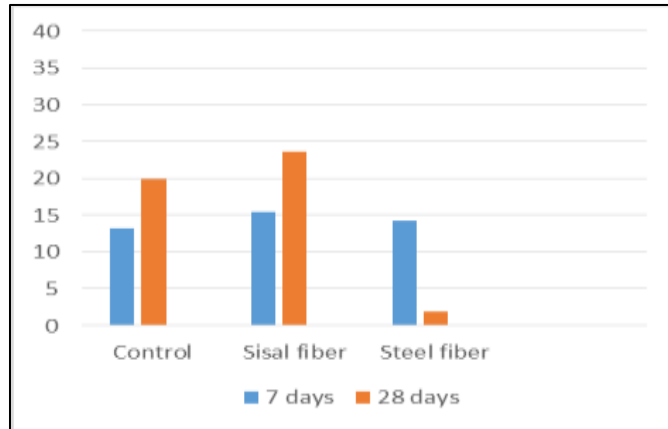


Fig. 9: % reduction in strength at 7 and 28 days

Table - VII
Result of Acid attack test for M20

Type of block	Percentage of fiber added	strength after 7 days (KN)	strength after 28 days (KN)
Control	-	13.14	19.92
Sisal fiber	1%	15.45	23.56
Steel fiber	1%	14.28	22.17

As shown in Table VII, in Acid attack test, percentage increase in strength of sisal fiber compared to control concrete after 7 days is 17.57% and increase in strength of steel fiber compared to control concrete after 7 days is 8.67%. After 28 days, percentage increase in strength of sisal fiber and steel fiber compared to control concrete are 18.27% and 11.29% respectively. Percentage increase in strength of sisal fiber compared to steel fiber after 7 days and 28 days are 8.18% and 6.26% respectively.

IV. CONCLUSION

After performing an experiment on sisal and steel fiber and also by comparison those with control block we can conclude that sisal fiber and steel fiber not only give better compressive and split tensile strength but it even helps to reduce the cracking on the surface. We also found that fibers could uniformly distribute all over the area, which could help to make a better bonding in concrete. The concrete mixture with sisal fiber has the highest compressive strength performance at all ages.

In tensile strength test, hint of steel fiber in concrete mix gave better results than concrete and sisal fiber mix. After 7 days it was 15.89% more operational and after 28 days it was 17.97% more effective than control concrete mixture.

In the case of durability test in acid attack test, sisal fiber concrete mix seemed to be highly effective compared to control and steel fiber mix although loss in mass was not desirable compared to concrete mix.

Used natural fiber's presence has shown some impressive data in compressive strength test and in test for durability. Sisal fiber can be practiced as admixture in concrete due to economical and environmental benefits, without bargaining in its execution, and it is cultivable all over the globe as well as it is environment friendly.

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