Experimental Investigation on Strength and Durability Properties of Sisal Fiber Reinforced Concrete for M30 Grade

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Abstract- *Concrete is the most widely used material throughout the world. Concrete is a brittle material which is good in compression but it is weak in tension, this leads to the formation of cracks, these cracks extend and reach the compression phase and finally the member breaks. It becomes necessary to find a best method to improve the strength of concrete by replacing cement with some natural material. A technique of introducing of natural fibers in concrete can be done. The influence of sisal fibers on the strength of concrete is taken as the main objective of this experimental study. The fiber diameter was first observed through micrometer gauge and was seen to be average 0.3mm. The sisal fibers were added with aspect ratio of 100 and the varying percentages of 0%, 0.5%, 1%, 1.5% and 2% in M30 grade of concrete and the mechanical properties such as compression, and split tensile were tested. Then the optimum fiber volume fraction for compressive strength was found. From the obtained optimum volume, the durability tests were conducted. The test results indicated that the sisal fibers were effective in improving the strength and durability of concrete.*

Key Words: Compressive strength, Split tensile strength, Sisal fiber, Optimum fiber volume, durability tests

1. INTRODUCTION

Concrete is a composite material composed of gravels (coarse aggregates), sand (fine aggregates) and hydrated cement (binder). Concrete is the most commonly used material for civil engineering construction. The infrastructure needs of our country are increasing day by day and it is necessary to enhance its characteristics by means of strength and durability.

The introduction of sisal fibers was brought in as an alternative to developing concrete in view of enhancing its compressive and tensile strengths. The basic governing principles between conventional concrete and fiber reinforced concrete having several characteristic variations; such as – fibers are generally short, closely spaced, and dispersed throughout a given cross section. The present investigation deals with the study on sisal fiber reinforced concrete, used for improving the properties of concrete. The usage of these natural fibers can improve the sustainability of cement composites by being renewable and are considerably less costly.

Fibers can be added to cement based matrices as primary or secondary reinforcement. Fibers work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. In these applications, the fibers act to increase both the strength and the toughness of the composite. In components such as slabs and pavements, fibers are added to control cracking induced by humidity or temperature variations and in these applications they work as secondary reinforcement. The use of fibers in concrete provides an exciting challenge to the construction industry for housing, for providing roofing sheets and to contribute to the rapid development of a country's infrastructure.

1.2 SISAL FIBER REINFORCED CONCRETE

Sisal fiber is one of the most widely used natural fibers and is easily cultivated. Sisal fiber is a leaf fiber extracted from the leaves of plant which is scientifically known as Agave sisalana. The Sisal plant is one of the types of perennial shrub which grows in the tropical and subtropical regions of the world. The failure strength and modulus of elasticity, besides the lengthening of rupture depend on the amount of cellulose and the orientation of the micro-fibers. The use of sisal fiber with a compatible matrix provided a new perspective for the use of natural fiber reinforced composites in the construction industry. Sisal is fully biodegradable and highly renewable resource of energy. The material is chosen to improve the various strength properties of the structure to obtain sustainability and better quality structure.

2. OBJECTIVES

- To study the effect of percentage of fiber added in to the concrete.
- To study the effect of fiber on different mix design.
- To analyze the mechanical properties such as compressive strength, split tensile strength of sisal fiber reinforced concrete.
- To analyze the optimum volume fraction of fiber based on the result of compressive strength.
- To study the durability properties of sisal fiber reinforced concrete.

3. MATERIALS USED

3.1 Cement

Ordinary Portland cement of 53 grade is used. The physical properties of the cement are given in the Table 1.

Table 1: Properties of Cement

Physical Properties	Results
Fineness	1.51
Standard consistency	34%
Initial setting time	More than one hour
Specific gravity	3.15
Soundness	1mm
Compressive strength of cement For 7 days	26.59MPa

3.2 Coarse Aggregate

The coarse aggregates used are crushed stone predominately retained on 4.75 mm sieve. The maximum size of aggregate used is 20mm.

3.3 Fine Aggregate

Aggregates used ae those passing through 4.75 mm sieve and predominately retained on 75µ sieve. M sand or manufactured sand is used in this thesis. The test conducted according to IS 2386:1963. From gradation curve it was found that the fine aggregate is of zone 2. The physical properties of aggregates are given in Table 2.

Table 2 : Properties of Aggregates

Physical Properties	Results	
	Coarse Aggregate	*Fine Aggregate*
Bulk Density	1.75	1.74
Specific Gravity	2.88	2.65
Void Ratio	0.65	0.53
Fineness Modulus	8.114	3.402
Uniformity Coefficient	1.76	5.55
Coefficient of Curvature	0.822	0.68

3.4 Sisal Fiber

Sisal fibers can be added to cement based matrices as reinforcement. Fibers work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. It can be used with an aspect ratio of 100 having fiber diameter of 0.3mm and fiber length of 30mm.

Fig 1: Sisal fiber

3.5 Water

In the concrete mix portable water that is free from oils and other impurities is used. The water used has no acidic or alkaline content in it.

3.6 Superplasticizer

CERA PLAST BLOCK IV, an admixture that helps to increase the workability has being used here. It is chemically Polycarboxylate (Ether) with a specific gravity of 1.11.

4. METHODOLOGY

Based on the objectives, a methodology for present thesis work has been adopted.

- Preliminary tests of materials were done.
- Mix design of M30 and SFRC with fibers added in varying percentage of 0%, 0.5%, 1%, 1.5% and 2% were prepared.
- Compressive strength and split tensile strength of 5 different mixes of M30 grade namely B0, B1, B2, B3 and B4.
- Compressive strength and split tensile strength of B0, B1, B2, B3 and B4 are tested for 28 days were found out.
- From the test result of compressive strength, the optimum volume fraction of fiber was found, while the split tensile strength improved with increase in volume fraction.
- From the obtained optimum volume of fiber, the durability test was conducted. Durability tests are as follows:
  - Acid attack test
  - Chloride attack test
  - Sulphate attack t est
  - Water absorption test

5. CONCRETE MIX DESIGN

The mix design for M30 grade is done according to IS 10262: 2009 and the conventional concrete with 0% sisal fiber can be represented by the letter B_0. B_1 represents the mix where 0.5% sisal fiber is added. B_2 represents the mix containing 1% of sisal fiber. B_3 represents the mix containing 1.5% of sisal fiber. And B_4 represents the mix containing 2% of sisal fiber. In all the mixes the amount of water used is kept constant.

6. EXPERIMENTAL INVESTIGATION

6.1 Compressive strength and Split tensile strength test

In order to find the compressive strength of different mixes 150 x 150 x 150 mm mould were filled with concrete. 30 cubes were casted. Six samples for each mix were casted and cured for 7 days and 28 days.

Fig 2: A_0 cube samples

15 cylinders were casted to find the split tensile strength of the mixes after 28 days of curing. The curing was done through ponding in a large water tank. A standard cylinder of size 150 x 300mm was used here. The load was applied on the surface of the cylinder diametrically and uniformly. The compression testing machine is used in this case also.

Fig 3: Split tensile strength testing with sample

6.2 Durability tests

6.2.1 Acid attack test

The concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed. The specimens were immersed in 5% Sulphuric acid (H_2SO_4) of pH 0.3 for a period of 56 days. The resistance of concrete to acid attack was found by calculating the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water. For this test, totally 6cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber.

6.2.2 Sulphate attack test

The concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed. The specimens were immersed in Sodium sulphate (Na_2SO_4) solution for a period of 56 days. The resistance of concrete to sulphate attack was found by calculating the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in sulphate solution. For this test, totally 6cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber.

6.2.3 Chloride attack test

The concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed. The specimens were immersed in Sodium Chloride (NaCl) solution for a period of 56 days. The resistance of concrete to Chloride attack was found by calculating the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in Chloride solution. For this test, totally 6cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber.

6.2.4 Water absorption test

The cubes of size 150 x150 x 150 mm were casted and tested after 28 days curing. The specimens were taken out and oven dried at a temperature of 100°C to 110°C for not less than 24 hours. Each specimen removed from the oven was cooled to 20°C to 25°C using dry air and the dry weight was determined. Then the specimens were immersed in water. The wet weights were recorded after 48 hours. Here, the water absorption test is carried on 1% of SFRC with conventional concrete of 0% sisal fiber. Therefore, totally 6 cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber.

Fig 4: Cubes after 1) Acid attack test, 2) Sulphate attack test, 3) Chloride attack test

7. RESULTS AND DISCUSSIONS

The results obtained from experimental tests conducted on SFRC with varying percentages of 0%, 0.5%, 1%, 1.5% and 2% are given below.

7.1 Compressive strength

It was observed that there was a considerable increase in compressive strength due to the addition of sisal fibers when tested for 7 and 28 days of curing. The compressive strength values for after 7 days and 28 days curing of the SFRC specimens with varying percentages are given in a table and the strength comparison of compressive strength with curing will be plotted in a graph also shown below.

Table 3: Compressive strength values

Mix	Average compressive strength for 7 days (N/mm^2)	Average compressive strength for 28 days (N/mm^2)
B0 – SF 0%	23. 56	33. 75
B1 -SF 0.5 %	24. 53	38. 93
B2 – SF 1%	25. 90	43.99
B3 – SF 1.5%	25. 40	40. 85
B4 – SF 2%	23. 76	35. 91

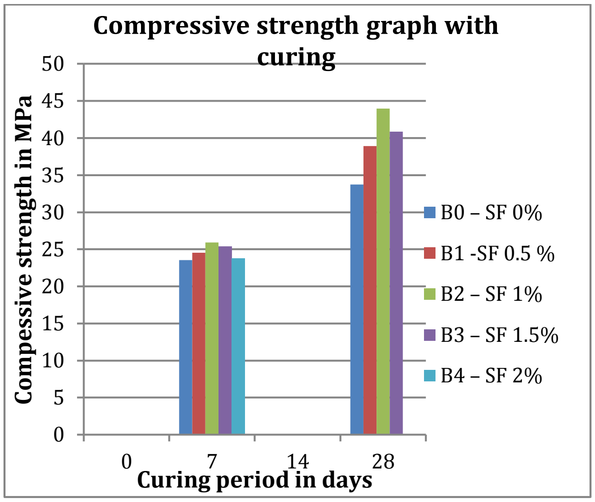

Fig 5: Graph showing compressive strength with curing

7.2 Split tensile strength

It was observed that there was a considerable increase in split tensile strength due to the addition of sisal fibers when tested for 7 and 28 days of curing. The split tensile strength values for after7 days and 28 days curing of the SFRC specimens with varying percentages are given in a table and the strength comparison of split tensile strength with curing will be plotted in a graph also shown below.

Table 4: Split tensile strength values

Mix	Average compressive strength for 7 days (N/mm2)	Average compressive strength for 28 days (N/mm2)
B0 – SF 0%	2.94	3.27
B1 -SF 0.5 %	3.44	4.89
B2 – SF 1%	3.81	5.94
B3 – SF 1.5%	3.64	5.33
B4 – SF 2%	3.17	3.82

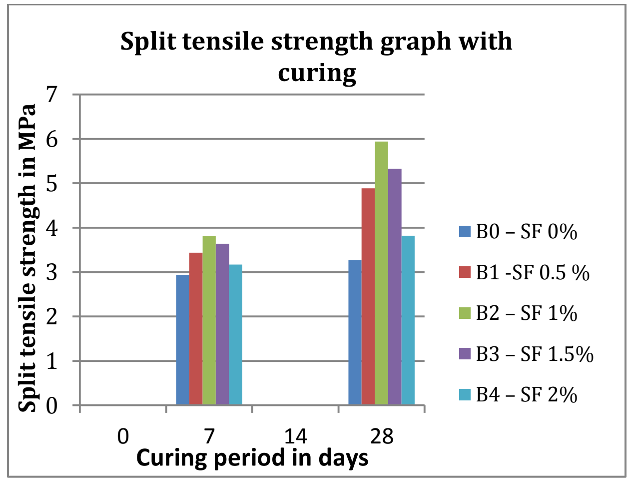

Fig 6: Graph showing split tensile strength with curing

7.3 Durability tests results

7.3.1 Acid attack test

From the results of acid attack test, loss in weight of cube specimen after immersion in Sulphuric acid solution and loss in compressive strength of cube specimen after immersion in Sulphuric acid solution of concrete can be represented in table given below.

Table 5: Loss in weight after immersion in H_2SO_4 solution of M30 grade concrete

Percentage of sisal fiber	% Mass reduction	
	Initial weight after 28 days curing	Final weight after 56 days immersing in H_2SO_4 solution
B_0 - 0% SF	7.82	6.56
B_2 - 1% SF	8.73	7.49

Table 6: Loss in strength after immersion in H_2SO_4 solution of M30 grade concrete

Percentage of sisal fiber	Strength reduction	
	28th day compressive strength	56th day compressive strength
B_0 - 0% SF	33.75	25.56
B_2 - 1% SF	43.99	36.39

7.3.2 Sulphate attack test

From the results of Sulphate attack test, loss in weight of cube specimen after immersion in Sodium sulphate solution and loss in compressive strength of cube specimen after immersion in Sodium sulphate solution of concrete can be represented in table given below.

Table 7: Loss in weight after immersion in Na_2SO_4 solution of M30 grade concrete

Percentage of sisal fiber	% Mass reduction	
	Initial weight after 28 days curing	Final weight after 56 days immersing in H_2SO_4 solution
B_0 - 0% SF	7.68	6.85
B_2 - 1% SF	8.49	7.72

Table 8: Loss in strength after immersion in Na_2SO_4 solution of M30 grade concrete

Percentage of sisal fiber	Strength reduction	
	28th day compressive strength	56th day compressive strength
B_0 - 0% SF	33.75	24.68
B_2 - 1% SF	43.99	35.45

7.3.3 Chloride attack test

From the results of Chloride attack test, loss in weight of cube specimen after immersion in Sodium chloride solution and loss in compressive strength of cube specimen after immersion in Sodium chloride solution of concrete can be represented in table given below.

Table 9: Loss in weight after immersion in NaCl solution of M30 grade concrete

Percentage of sisal fiber	% Mass reduction	
	Initial weight after 28 days curing	Final weight after 56 days immersing in H_2SO_4 solution
B_0 - 0% SF	7.51	6.70
B_2 - 1% SF	8.53	7.83

Table 10: Loss in strength after immersion in NaCl solution of M30 grade concrete

Percentage of sisal fiber	Strength reduction	
	28th day compressive strength	56th day compressive strength
B_0 - 0% SF	33.75	26.73
B_2 - 1% SF	43.99	33.51

7.3.4 Water absorption test

The water absorption test result of concrete can be represented in a table given below.

Table 11: Water absorption test sample values

Mix	Sample 1		Sample 2		Sample 3	
	Initial(kg)	Final (kg)	Initial(kg)	Final(kg)	Initial(kg)	Final(kg)
B_0	8.63	8.37	8.86	8.56	8.86	8.56
B_1	8.84	8.49	9.37	9.02	9.37	9.02

Table 12: Water absorption test results

Mix	Sample 1	Sample 2	Sample 3
	W.A (%)	W.A (%)	W.A (%)
B_0 –0% SF	3.17	3.50	2.47
B_1 –1% SF	4.12	3.88	2.83

8. SUMMARY AND CONCLUSIONS

On studying the SFRC with varying percentages of adding sisal fibers by weight of cement, it can be concluded that,

1. The addition of sisal fiber into the concrete significantly increases the strength properties of the concrete.
2. It was observed that the addition of fibers increased the compressive strength of concrete for varying dosages of 0.5%, 1%, 1.5% and 2% and was found to be 18%, 35%, 24% and 7% more than that of conventional concrete of 0% sisal fiber. The maximum percentage increase in compressive strength was achieved at 1% of fiber dosage.
3. It was observed that the addition of fibers increased the split tensile strength of concrete for varying dosages of 0.5%, 1%, 1.5% and 2% and was found to be 54%, 89%, 68% and 18% more than that of conventional concrete of 0% sisal fiber. The maximum percentage increase in split tensile strength was achieved at 1% of fiber dosage.
4. SFRC is more resistant to acid attack, sulphate attack, and chloride attack when compared to conventional concrete of 0% sisal fiber. In all cases the maximum resistance was observed in case of SFRC with 1% of fiber dosage.
5. It was also observed that water absorption value increases in 1% of fiber dosage than conventional concrete of 0% sisal fiber in each grade of concrete. It reveals that the fiber added into the

concrete, the pores are increased the amount of water absorption also increased.

6. From the above experimental study, it can be concluded that addition 1% of sisal fibers by weight of concrete enhances its strength and durability considerably.

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