

EFFECT OF FIBRE LENGTH AND PERCENTAGE OF SISAL ON STRENGTH OF CONCRETE

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Abstract: Natural fibres are used since many centuries for different purposes since the beginning of civilization. They have been used for ropes, toughening of pots etc since many centuries. Natural fibers are of two types. Natural inorganic fibers such as Basalt, Asbestos etc and the other are the natural organic fibers such as coconut , palm, kenaf, jute, sisal, banana, pine, sugarcane, bamboo etc. The natural fibers are investigated by different researchers as construction materials that can be used in cement paste/mortar/concrete. The present work is carried out to evaluate the compressive, Tensile as well as Flexural strength of concrete using sisal fibres as reinforcement. By using different fibre Aspect ratio and fibre percentage, effect on compressive strength of concrete cube specimen for various combinations is studied. The fibre diameter was first observed through micrometer gauge and was seen to be average 0.3mm. Fibres used with aspect ratio 50, 75,100 and the percentage of 0.5%, 1%, 1.5% and 2% were used for the work. Normal M20 mix was used for the study. The experimental work was carried out for twelve different combinations. The obtained specimens were subjected to tests aimed to check the compressive strength. An increase in compressive strength by 69.27 % and was observed at 1% fibre and 50 A.R.

Keywords: Natural fibre, Sisal, Strength of concrete

1. INTRODUCTION

Concrete is a brittle material. It possesses a low tensile strength, ductility and very little resistance to cracking. Internal micro cracks are present in concrete and its poor tensile strength is due to propagation of such micro cracks leading to brittle fraction of concrete. In plain concrete and similar brittle materials, structural cracks develop even before loading due to drying shrinkage and other causes. When load is applied the internal cracks propagate and open up due to stress and additional cracks are formed. The development of these cracks is the cause of inelastic deformation in concrete.

The natural fibres have been tried as reinforcement for cement matrices mainly to produce low-cost thin elements for use in housing schemes. Vegetable fibres require only a low degree of industrialization for their processing and in comparison with an equivalent weight of the most common synthetic reinforcing fibres, the energy required for their production is small and hence the cost of fabricating these composites is also low. In addition, the use of vegetable fibres in cement matrices requires only a small number of trained personnel in the construction industry

1.1 Sisal Plant

Sisal fibre is a leaf fibre 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. It is one of the most extensively cultivated hard fibres in the world. It grows in very hardy type soils where normal plants may not be grown. Though, the ideal condition in which the plant may be cultivated are in the areas where average temperature is between 20 to 28°C and the average annual rainfall is between 600 to 1500 mm. The main advantage of this plant is that, it can be grown where prolong droughts and high temperature are the problems where other plants cannot be grown.[17]

2. THEORETICAL BACKGROUND



Fig.1: Sisal Cultivated Farm

The interactions between the fibre and cement matrix or concrete ingredients, as well as the structure of fiber reinforced cementitious material are the most affecting properties to the performance of a cement based fibre composite material. In cement based composites the two major roles played by the fibres are to improve the toughness and the post-cracking

performance of the matrices. However, to understand these properties, the need for estimating the fibre contribution and the prediction of the composite's behavior is necessitated. Such considerations included are:

- The matrix composition.
- The Length of the fibres used.
- Type, geometry and surface characteristic of the fibres.
- The orientation of fibres through the cement matrix.
- Percentage of the fibre used in the matrix.
- The ratio of fibre modulus to matrix modulus in the composite.

2.1 Volume Fraction of Fibre

Volume percentage of the fibre is the important criteria which should be considered while designing the composites. Compressive strength is essentially unaffected by the inclusion of a low percentage fraction of fibres in the composite (< 0.5%). At a volume fraction of 2% to 3% the compressive strength can be reduced by about 25% to 30% for low modulus fibres while for high modulus fibres, there is generally some increase in compressive strength.

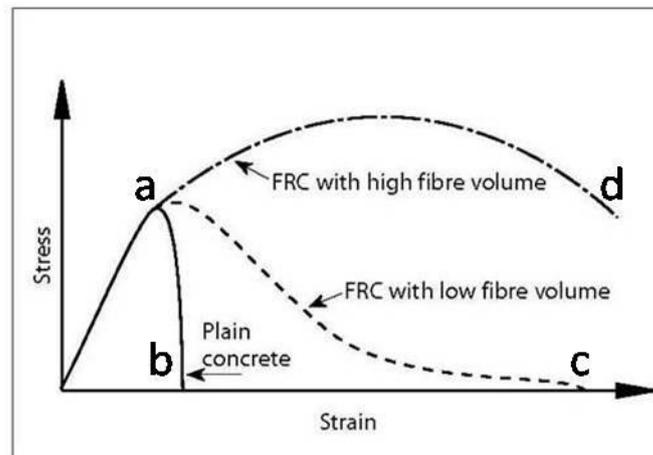


Fig 2: Behavior of Composite with respect to volume percent of Fibres.

For volume fractions of steel fibres up to 1.5% compressive strength increases of up to 25% have been recorded for normal concrete. For high fibre contents (around 10%) up to three-fold increase of matrix strength can be achieved for slurry infiltrated concrete [1]. Except at very high fibre contents, the tensile strength of the composite is dominated by the matrix strength. Stiff fibres produce some increase in strength, while soft fibres usually have little effect on the composite [1]. After first cracking, load is transferred to the fibres at the crack site and one of several types of behavior may then be observed, depending on the strength, volume fraction and length of fibres. Fig 2 describes the pre and post-cracking behavior of a tensile test specimen. Three different responses are shown for different fibre contents are shown in the figure. Complete failure of the composite occurs at a, b, c and d for the different concentrations of the fibres. [1, 8].

3. SYSTEM IMPLEMENTATION

For the present work, we have used the sisal fibre in two combinations, A) The Aspect ratio is varied as 50, 75 and 100 as well as B) The percentage of the sisal is varied in four combinations such as 0.5%, 1%, 1.5% and 2%.

For each combination the samples are casted in M20 mix and tested for its Compressive, Tensile and flexural strength of the concrete specimen. First of all we have to evaluate the quantity of fibre used for each combination. Table 5.1 gives the quantity required in grams for each combination. Slump cone test on fresh concrete in plastic stage is also conducted in order to determine the workability of concrete.

3.1: Preparation of mix

Mixing is an important process in which the ingredients of concrete are thoroughly mixed in order to get the homogeneous mass of concrete. For this work, the tilting mixer was used to mix the concrete. The aggregate are placed in the mixer and the mixer is started. The cement is then poured in the mixer and the mixer is rotated to about 30 seconds, then the water is added to the mix and while the further mixing is going on, the sisal fibre is added in the mix. Sisal fibre was added in the wet mix because it was observed that if the sisal is added in dry mix; fibre balls are formed and the fibres are not properly and uniformly mixed in the concrete. After mixing, the concrete is tested for its workability.

3.2 Workability

Workability is an important property of fresh concrete, which shows the behaviour of concrete from mixing to till finishing .The concrete high consistency and which may be more workable need not be of right workability for particular job. Every job requires different type of consistency and workability. Workability by slump test shows the behaviour of contacted concrete under the action of gravitational forces. The target mix was assumed to be of the slump between 50 to 75mm. The average slump value of the concrete used in the study with water cement ratio 0.50 is found to be 68.33 mm.

3.3: Casting of Concrete Specimen

Four batches are carried out depending upon the percentage of sisal fibre added to composites as 0.5%, 1%, 1.5% and 2% of sisal fibre. Again each batch was carried out with aspect ratio of 50, 75, 100. The moulds are casted separately depending upon the aspect ratio and corresponding batches. Six moulds of each combination are casted for testing after 7th and 28th day from casting.

% of sisal fibre	0.50%			1%			1.50%			2%			Total Quantity	
	Aspect ratio	50	75	100	50	75	100	50	75	100	50	75		100
Cube	6	6	6	6	6	6	6	6	6	6	6	6	6	72
Cylinder	6	6	6	6	6	6	6	6	6	6	6	6	6	72
Beam	6	6	6	6	6	6	6	6	6	6	6	6	6	72

Table 1: Number of moulds for Testing

4. RESULT AND DISCUSSIONS

There are in total 12 different combinations of fibre dosage. While mixing the concrete, the fibres are randomly spread in the plastic concrete at the time of mixing.

4.1: Compressive Strength of Concrete cubes (150 x 150 x 150 mm)

Details of sisal Insertion	7 Days Strength (N/mm ²)	28 Days Strength (N/mm ²)
(0%) Normal M 20 Concrete	21.10	29.26
0.5% - 50 A. R. + Normal Concrete	27.03	36.00
0.5% - 75 A. R. + Normal Concrete	28.52	39.78
0.5% - 100 A. R. + Normal Concrete	39.04	40.89
1% - 50 A. R. + Normal Concrete	37.19	49.53
1% - 75 A. R. + Normal Concrete	23.41	32.81
1% - 100 A. R. + Normal Concrete	39.26	47.33
1.5% - 50 A. R. + Normal Concrete	37.85	41.41
1.5% - 75 A. R. + Normal Concrete	25.93	31.41
1.5% - 100 A. R. + Normal Concrete	31.19	34.15
2% - 50 A. R. + Normal Concrete	38.74	48.52
2% - 75 A. R. + Normal Concrete	29.26	41.11
2% - 100 A. R. + Normal Concrete	27.26	39.85

Table 2: Compressive Strength test Results.

It is to be noted from the above results that, for all the combinations of sisal, the compressive strength is found to be greater than that of the normal concrete (0% insertion) after 28 days curing. From the obtained results that, compressive strengths for 1% sisal insertion are seen to be maximum for 7 and 28 days strength results. Here it is seen that for 7 days strength 1% sisal with Aspect ratio 100 gives the highest strength on 7 days curing. But after 28 days curing sisal fibre 1% with Aspect ratio 50 shows the highest strength. The strength of concrete is found to be increased by 69 %. From the graphical representation for the strength results cumulatively it is seen that, Strength consistently increases from 0 % to 1% sisal with 50 A. R. and after this the graph shows undulations reflecting the decreasing and increasing results. It suddenly drops down at 1% with A.R. 75. It is considerable that, the results for 2% sisal fibre with 50 A. R. are second highest for the 7 as well as 28 days results

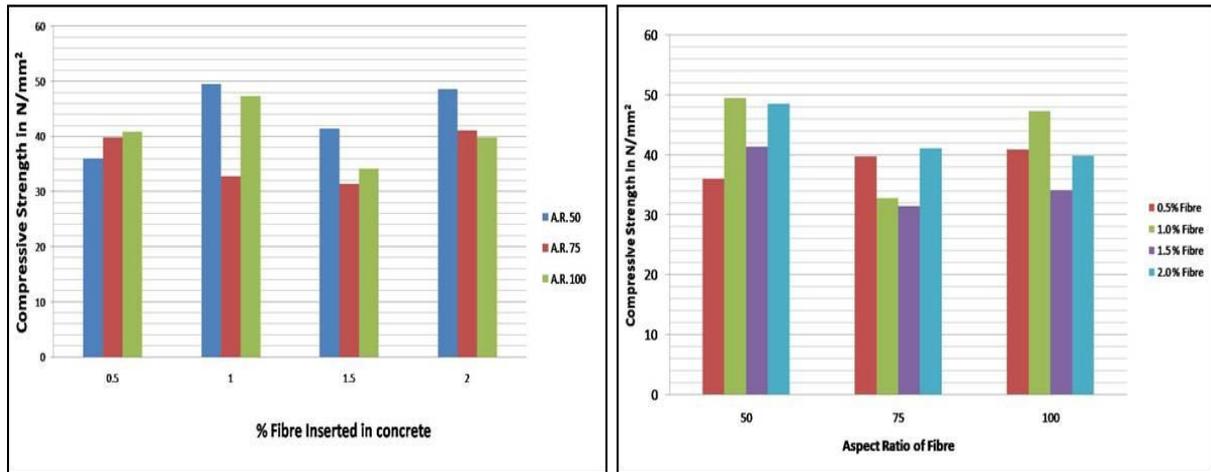


Fig 3: Compressive strength variation with Aspect Ratio and volume percent of Fibres.

4.2: Split Tensile Strength of Concrete cylinders (150 mm dia x 300 mm)

Details of sisal Insertion	7 Days Strength (N/mm ²)	28 Days Strength (N/mm ²)
(0%) Normal M 20 Concrete	1.56	2.85
0.5% - 50 A. R. + Normal Concrete	2.37	3.11
0.5% - 75 A. R. + Normal Concrete	1.86	2.84
0.5% - 100 A. R. + Normal Concrete	1.71	3.02
1% - 50 A. R. + Normal Concrete	3.18	3.55
1% - 75 A. R. + Normal Concrete	2.52	3.28
1% - 100 A. R. + Normal Concrete	3.16	3.68
1.5% - 50 A. R. + Normal Concrete	3.21	3.68
1.5% - 75 A. R. + Normal Concrete	2.80	3.46
1.5% - 100 A. R. + Normal Concrete	3.11	3.66
2% - 50 A. R. + Normal Concrete	2.60	3.15
2% - 75 A. R. + Normal Concrete	2.38	3.05
2% - 100 A. R. + Normal Concrete	2.30	3.21

Table 3: Average Split Tensile Strength test Results

It has been seen from the obtained results that, tensile strength of concrete is improved by the insertion of sisal in concrete; almost all the strengths are seen to be improved, except the combination of 0.5% -75 A.R., in this particular combination average 28 days strength is slightly below the average 28 days strength of specimen without fibre. It is seen that as like compressive strength, the maximum 28 days strength is seen for 1% sisal insertion with A.R. 100.

Here it is noted that the same strength is also seen for the combination, 1.5% sisal with A. R 50. For the 1%- A.R. 50 combination however, the strength achieved at early stage of 7 days is high but the strength is later not improved well. If we evaluate results graphically, we may observe that the 7 and 28 days strength of the specimens are seen to be similar. The results

are shown graphically in the Figure 6.5. From the below graph it is seen that the tensile strength of the concrete can be improved by insertion of fibres with fibre dose between 1% and 1.5%, the graph shows the steady profile with less undulations for any combination of fibre dosage 1% and 1.5%, for fibre dosage less than 1%, and greater than 1.5% the Tensile strength gradually reduced.

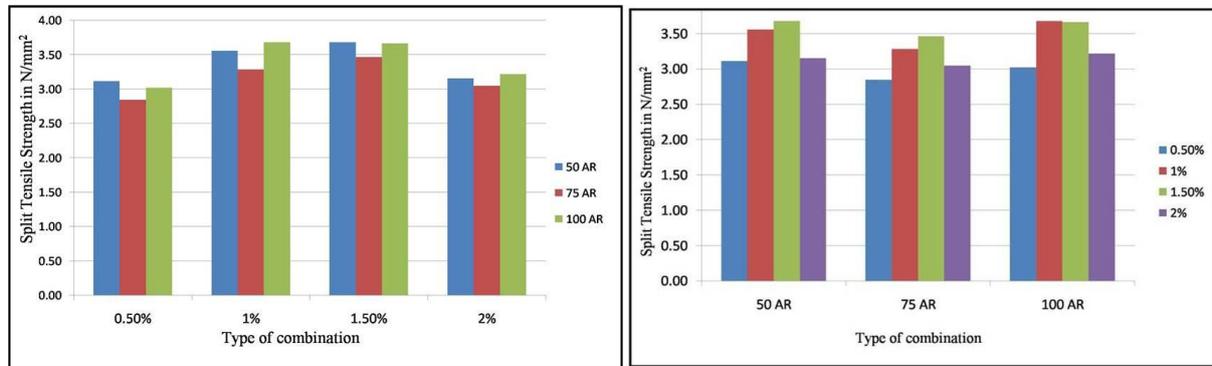


Fig 4: Split Tensile strength variation with Aspect Ratio and volume percent of Fibres.

4.3: Flexural Strength of Concrete Beams (150 x 150 x 700 mm)

Details of sisal Insertion	7 Days Strength (N/mm ²)	28 Days Strength (N/mm ²)
(0%) Normal M 20 Concrete	2.95	3.95
0.5% - 50 A. R. + Normal Concrete	3.07	3.82
0.5% - 75 A. R. + Normal Concrete	3.25	5.54
0.5% - 100 A. R. + Normal Concrete	3.08	7.23
1% - 50 A. R. + Normal Concrete	4.25	5.87
1% - 75 A. R. + Normal Concrete	3.47	6.64
1% - 100 A. R. + Normal Concrete	2.94	7.13
1.5% - 50 A. R. + Normal Concrete	4.26	5.92
1.5% - 75 A. R. + Normal Concrete	3.52	6.75
1.5% - 100 A. R. + Normal Concrete	3.61	7.41
2% - 50 A. R. + Normal Concrete	2.80	6.89
2% - 75 A. R. + Normal Concrete	3.30	6.48
2% - 100 A. R. + Normal Concrete	3.60	7.03

Table 4: Average Flexural Strength test Results

The obtained results for the Flexural strength of concrete are very different than the results for split Tensile strength. Though the results are improved by the insertion of sisal in concrete; strengths for some of the combinations with sisal are less than the normal concrete results without fibre at early stage of curing. The difference in the strengths is less but it is observed that at moderate percentage of fibre (1%) with maximum A.R. the strength is reduced, also; for high percentage fibre, with smaller A.R. (50 A.R.) results are seen to be lowest of all the values for earlier stage of curing. (7 days). While after 28 days curing, the altogether different strength pattern is observed.

If we observe average 28 days strength, it is seen that the Flexural strength is directly proportional to the Aspect ratio of the fibre irrespective of the percentage of fibre. This may be because of high pull out strength of the fibre under the action of bending. It is seen in all the four percentage combinations that, the flexural strength increases with the increase in the length of fibre. The highest strength of the 28 days cured samples is observed for the 1.5% sisal with 100 A.R. Also the values for 100 A.R. for all the percentage of fibre are very close strength results.

The results are shown graphically in the Figure 6.9. From the below graph it is seen that the strength of beam in flexure under three point bending test on UTM, the concrete strength is improved by insertion of fibres with fibre dose with high A.R. of 100 for all the combination of percentages. The 28 days strength is shown by graph very much comparative values for 100A.R.

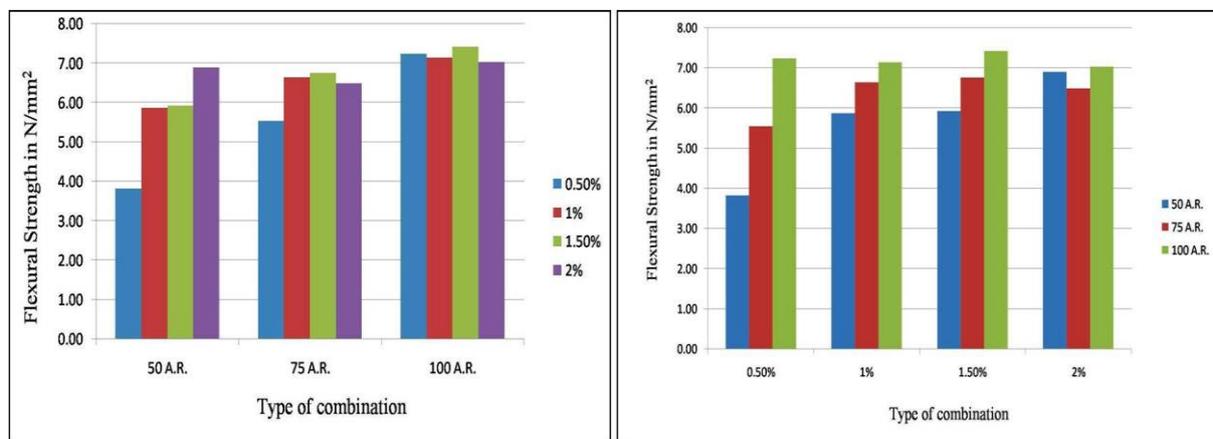


Fig 4: Flexural strength variation with Aspect Ratio and volume percent of Fibres.

5. CONCLUSION AND SCOPE FOR FURTHER STUDIES

5.1 Conclusion

It is found that the use of fiber in the concrete decreases the workability of the fresh concrete to some extent. Though the workability decreases, the strength parameters have shown very promising results. Following are the conclusive findings of the Tests.

5.1.1 Compressive Strength:

1. The obtained results for various combinations have shown that the compressive strength of the concrete is increases with percentage increase but after 1% fibre dosage the strength is seen to be reduced gradually.
2. Also if we compare the results on the parameters of length of fibre. At low fibre length the compressive strength is seen to be maximum. It reduces as the fibre length increased from A.R. 50 to A.R. 75, and again the strength is seen to be increased for A.R. 100, this shows that the compressive strength is more at low A.R.
3. The maximum compressive strength is observed at 1 % fibre with aspect ratio 50 which is 69.27 % more than the average compressive strength without fibre.

5.1.2 Tensile Strength:

1. The tensile strength increased with the increase in fibre percentage, there seen to be gradual increase in the strength from 0.5% to 1.5% and then there is a decrease in the tensile strength.
2. With the variation of fibre length, it is seen that, the moderate aspect ratio of 75 gives the very poor results, where as for low and high length fibres there is improvement in the tensile strength.
3. The maximum tensile strength is at 1% fibre with 100 A.R. and 1.5% fibre with 50 A.R. which is 29.14% more than the concrete strength without fibre.

5.1.2 Flexural Strength:

1. The flexural strength is improved with the increase in the percentage fibre up to 1.5% after that there is a little decrease in the flexural strength. For short fibres however the strength increases continuously from 0.5 to 2% fibre variation.
2. If we analyse the strength results with respect to change in the aspect ratio, the strength is shown to be increased continuously with the increase in the aspect ratio, at aspect ratio 100 strengths for all the percentage of fibre, are very near to each other, while at aspect ratio 50 there is marginable difference in the strength of concrete at various percentages.
3. The maximum flexural strength is at 1.5% fibre with aspect ratio 100 which is 87.71% more than the concrete strength without fibre.

5.2 Recommendation for Further Studies

Recommendations for further studies are as mentioned below.

- Though the problem of the reduction in workability of the fresh fiber reinforced concrete is not influencing the strength pattern if the water absorption of fibre is considered while designing the concrete, by adding chemical admixture such as super plasticizer, silica fume or blast furnace slag etc, this problem may be reduced.
- More laboratory investigations and tests should be conducted to study on the other Mechanical properties of Sisal fibre reinforced concrete with different grades of concrete.
- Natural fibres are generally subjected to aging process after certain duration of time, therefore the effect of aging of sisal fibre is to be studied and the strength decrement of fibre reinforced concrete after long term age are to be evaluated.
- The combination of fibres may tend to provide more efficient mechanical properties of structure. Further investigation can be carried out by combination of different types of fibers into the concrete mix.

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