Experimental Study on Flexural Behavior of Sisal Fibre in Reinforced Concrete Beam

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Abstract: **- Conventional concrete is strong in compression and weak in tension in order to overcome the weakness steel reinforcement is being provided. Researches attempted to inherit the tensile property by introducing synthetic fibres such as poly propylene, asbestos etc., and steel fibres, but they are expensive. Hence they are attempting to use the natural fibres such as straw, elephant grass, palm leaf, coconut coir etc. to incorporate tensile strength in conventional concrete. So that the traditional steel reinforcement on concrete can be reduced.**

In this research, sisal is being used in concrete. Thereby, the mechanical properties such as compressive strength, split-tensile strength, and modulus of rupture of M40 grade concrete and by varying the dosage of fibre content from 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%, by volume of cement with optimum length of 35mm obtained from literature review, were found. The optimum dosage of sisal fibre was found to be 0.3%. The flexural behaviour of reinforced concrete beams with 0.3% sisal fibre was compared with conventional concrete properties of M40 grade.

Keywords: Fibre reinforced Concrete, hardened property, sisal fibre,

1. INTRODUCTION:

Natural fibre has special appeal in the field of civil engineering. The cost of natural fibre is expected to be price competitive. The advantages of natural fibre materials are strength, better durability, competitive cost, environmental compatibility and bio degradability. The use of natural fibre in concrete is recommended since several types of fibres are available locally and are plentiful for eg. Straw, coconut coir, palm leaf, cotton, sisal, sugarcane, bamboo, jute, wood etc.. Of all natural fibres, sisal is hard and tough fibre, polygonal to round in section has the greatest tearing strength and retains this property even in wet condition. Sisal is a bio degradable organic fibre material containing 46% lignin, 54% cellulose. Because its high content of lignin, sisal is much more advantageous than other natural fibres.

Fibres can be added to cement based matrices as primary or secondary reinforcement. Fibres work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. In these applications, the fibres act to increase both the strength and the toughness of the composite. In components such as slabs and pavements, fibres are added to control cracking induced by humidity or temperature variations and in these applications they work as secondary reinforcement.

Vegetable fibres, including sisal, coconut, jute, bamboo and wood fibres, are prospective reinforcing materials and their use until now has been more empirical than technical. They have been tried as reinforcement for cement matrices in developing countries 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 (Aziz et al., 1984). In addition, the use of a random mixture of vegetable fibres in cement matrices leads to a technique that requires only a small number of trained personnel in the construction industry. The use of such fibres 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. Vegetable fibre cement composites thus pose the challenge and the solution for combining unconventional building materials with traditional construction methods

The use of sisal, a natural fibre with enhanced mechanical performance, as reinforcement in a cement based matrix has shown to be a promising opportunity. The cement matrices can consist of paste, mortar or concrete. Most of the studies on sisal fibre concrete involve the use of ordinary Portland cement. However, high alumina cement, cement with additives such as fly ash, slag, silica fume have also been used to improve the durability of the composites.

2.LITERATURE REVIEW:

The cut fibres with a length of 10-30mm were cast into beams and an improvement in the tensile strength in bending was observed for fibre reinforced specimens. It was found that toughness increased markedly when continuous fibre were used. Their results on the flexural static strength and toughness of beams made of cement based matrices reinforced indicated that remarkably high strengths can be achieved using suitable mixing and casting techniques with

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optimum fibre volume fraction. (Nilsson and Kavin G. 1975)

The influence of sisal fibres on the minimizing of plastic shrinkage in the pre-hardened state, on tensile, compressive and bending strength in the hardened state of mortar mixes improved. Development of production techniques for manufacture keeping in view that it must be cost-effective. Physical and mechanical properties, impact and abrasive resistance, water absorption, shrinkage, chemical resistance, acoustic requirements, thermal performance and durability of sisal fibre cement based products should be thoroughly evaluated so as to arrive at a series of composites to be used in rural and civil construction. Design procedures must also be standardized. The results show that the composites reinforced with sisal fibres are reliable materials to be used in practice for the production of structural elements to be used in rural and civil construction.(Kuruvilla Joseph,1999 et al)

Experimental characterization of sisal fibre reinforced concrete showed that incorporating fibre into the concrete mixture is beneficial. Optimum performance for a matrix having sisal fibre as reinforcement is at 3% fibre volume fraction, with 70mm fibre length and at a water-cement ratio of 0.6. (Augustine Uche Elinwa, 2003 at al)

Thermal conditioning of woven sisal fibre was carried out, followed by the development of woven sisal fibre reinforced polymer composite system, and its tensile and flexural behaviour was characterized. It was observed that thermal conditioning improved the tensile strength and the flexural strength of the woven sisal fibre composites, which were observed to bear superior values than those in the untreated ones. (Jagannatha Reddy H.N 2007, at al)

Concrete reinforced with sisal fibre and using Iraqi bauxite exhibited improvement in flexural strength and splitting tensile strength while a small reduction in compressive strength was reported. The addition of sisal fibre improved the flexural strength and splitting tensile strength of plain concrete. The increase in flexural strength at age of 28 day represented by (7.7%, 13.6% and 9.1%) for concrete reinforced with sisal fiber with (0.5%, 1.0% and 1.5%) respectively and at age of 90 day the improvement in flexural strength represented by (15.3%, 16% and 5.2%) for the same percentage of fibre respectively. (Kawkab Habeeb Al Rawi, 2009)

The study of sisal fibre as concrete reinforcement material in cement based composites. A brief description on the use of the cement based composite materials as building products has been included. The influence of sisal fibres on tensile, compressive and bending strength in the hardened state of mortar mixes is discussed. The durability of natural fibres in cement based matrices is of particular interest and is also highlighted. From the hysteresis stress-strain curves it was noticed no signs of degradation for maximum stress level .For maximum stress levels; there was an increase in the hysteresis area and decrease in the Young´s modulus. (Yogesh, 2013 at al)

3. SCOPE AND OBJECTIVE:

The scope of this investigation is find out the behavior of sisal fiber in concrete, thereby optimum amount of sisal fiber that can be used in various application such as pavements, industrial floors, etc thus enhance the concrete quality.

The main objective of this research is to study the following properties.

- Mechanical properties such as compressive strength, tensile strength, flexural behaviour of reinforced concrete beams by introducing the sisal fibre.
- To study the stress strain relation of the beams and crack pattern.
- To study the Ductility and Stiffness.

4. MATERIALS USED:

4.1 Cement

The cement used in this experimental investigation was 53 grade OPC manufactured by Chettinad cements.

4.2 Fine Aggregate

The sand used for experimental program was locally procured and conforming to zone II. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. The fine aggregates were tested as per Indian Standard Specification IS: 383-1970.

4.3 Coarse Aggregate

Locally available coarse aggregates were used in this work. Aggregates passing through 20mm sieve and retained on 4.75mm sieve were sieved and tested as per Indian Standard Specifications IS: 383-1970.

4.4 Super Plasticizer

The super plasticizer used in this project conform the guide lines drawn by IS 9103-79, ASTM C 494 Type D. Enfiq super Plast-400 (super plasticizer water reducing admixture) is used in this project. Physical properties of Super Plasticizer are based on manufacture's catalogue.

- Color : Brown
- Type : liquid
- Specific gravity : 1.170-1.190

4.5 Sisal Fibre

The use of sisal, a natural fibre with enhanced mechanical performance, as reinforcement in a cement based matrix has shown to be a promising opportunity. Figure 4.1 shows the sisal fibre.

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Fig 4.1 Sisal fibre

The Properties of Sisal fiber are given below

- Density : 1.33 g/cm^3
- Tensile Strength : 600-700x10^6 N/m^2
- Modulus of elasticity :38 Gpa
- Elongation at failure :2-3%
- Moisture absorption : 11%

4.6 MIX PROPORTION

Concrete mix design is a process by which the proportions of the various raw materials of concrete are determined with an aim to achieve a certain minimum strength and durability, as economically as possible. Based on the simplified mix design procedure, a concrete mix of proportions with characteristic target mean compressive strength of 40 Mpa was designed without any mineral admixtures. The concrete mix was designed as per IS 10262:2009 for M40 grade of concrete. The mix adopted for the study is given in Table 4.1.

Table 4.1 Mix proportion

Water	Cement	Fine aggregate	Coarse aggregate (20mm)	Coarse aggregate(10 mm)	Superplasticiser
0.36	1	1.638	1.782	1.188	0.005

4.7 DESCRIPTION OF SPECIMEN

4.7.1 Cube

Cube moulds of size 150x150x150 mm were used. The cube moulds were cleaned thoroughly using a waste cloth and then properly oiled along its faces. Concrete was then filled in mould and then compacted using a standard tamping rod of 600mm length having a cross sectional area of 25mm^2

4.7.3 Prism

Prism moulds of size 100x100x500 mm were used. The cube moulds were cleaned thoroughly using a waste cloth and then properly oiled along its faces. Concrete was then filled in mould and then compacted using a standard tamping rod of 60 cm length having a cross sectional area of 25mm^2.

4.7.4 Beam

A totally six specimens of Rectangular reinforced concrete beams were casted. There are three specimens are conventional beams and another three are adding 0.3% of sisal fibre in reinforced concrete beams are to be tested in this project. Table 4.2 shows the description of specimens in this project.

Table 4.2 Description of specimens

S.No	Description	Number of Specimen					
		CSP	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**
1	Cube	6	6	6	6	6	6
2	Prism	3	3	3	3	3	3
3	Beam	3			3		

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Where,

CSP- Control Specimen

SP1-Specimen with 0.1% Sisal Fibre by weight of cement

SP2-Specimen with 0.2% Sisal Fibre by weight of cement

SP3-Specimen with 0.3% Sisal Fibre by weight of cement

SP4-Specimen with 0.4% Sisal Fibre by weight of cement

SP5-Specimen with 0.5% Sisal Fibre by weight of cement

4.8 REINFORCEMENT DETAILS

Cross sectional details and longitudinal details of R.C.C rectangular beams are shown in Figure 4.2.

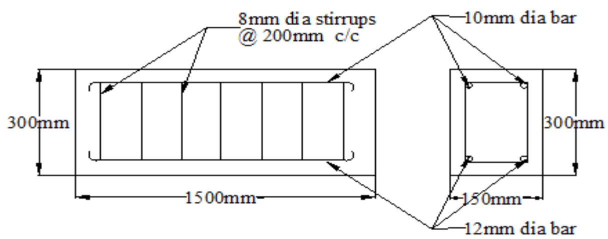

Fig 4.2 Reinforcement details

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4.9 CASTING OF SPECIMENS

The mix proportion is arrived for normal concrete mix. Based on the mix design the required quantities of concrete ingredients are taken. The materials are mixed either by hand mix or machine mix. The mixing time is taken for concrete to obtain cohesive nature after the completion of mixing, the concrete is placed into concrete moulds and the concrete is filled in the moulds by three layers in which three layers is tamped by 25 times with a tamping rod for compaction after that the concrete moulds are placed in vibration table for obtaining sufficient compaction. Figure 4.3 shows the casted specimen of M40 concrete by adding 0.3% of sisal fibre in volume of cement.

Fig 4.3 Specimens after casting

4.7 CURING OF SPECIMENS

The specimens were carefully casted and demouled after 24 hours, without disturbing the specimens, these were cured in the curing tank for 7 and 28 days.

5. RESULTS AND DISCUSSION

5.1 GENERAL

This chapter describes the workability characteristics of fresh concrete and static experimental results of beams. The behavior throughout the static test to failure is described using recorded data on deflection behavior and the ultimate load carrying capacity. The crack patterns and the modes of failure of each beam, ductility, stiffness, percentage of reduction in stiffness, energy absorption and energy ductility were discussed.

5.2 WORKABILITY OF CONCRETE

5.2.1 Slump Value

The slump value decreased with increase in percentage of sisal fibre. The graphical representation is shown in Figure 5.1. Fresh concrete or plastic concrete is a freshly mixed material which can be molded in to any shape the relative quantities of cement ,aggregates and water mixed together control the wet state as well as in the hardened state.

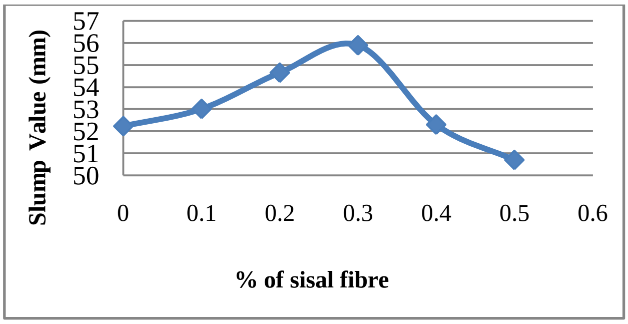

Fig 5.1 Slump value of concrete Mix

5.3 TESTS ON HARDENED CONCRETE

One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works were conducted the compressive strengthen test on cubes for 7 days and 28 days compressive strength, modulus of rupture test conducted on the prism and split tensile strength were conducted on the cylinder, and flexural strength test conducted on the reinforced concrete beam.

5.3.1 Compressive Strength

From the compressive strength results obtained for both 7 days and 28 days it was observed that the compressive strength increased by adding 0.3% of sisal fibre and there was a decrease in strength upon further addition in percentage of sisal fibre in concrete. Hence 0.3% addition of sisal fibre in volume of cement in concrete was considered as optimum. The 7th day and 28th compressive strength of concrete for addition of sisal fibre in volume of cement by various percentage is shown in Figure 5.2.

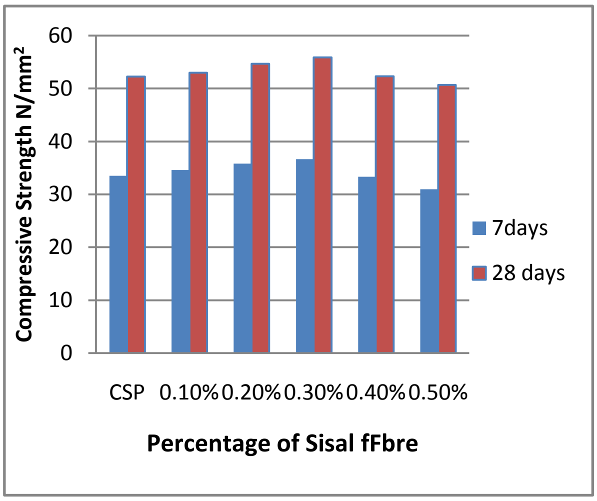

Fig 5.2 7th day and 28th day Compressive strength results

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5.3.2 Flexural Strength Test

RCC beams were cast for controlled concrete and M40 grade concrete with 0.3% addition of sisal fibre and tested as shown in figure 5.3

Fig 5.3 Displacement measurement of concrete beam

For M40 grade concrete RCC beam, the initial crack load was found as 90 kN, the ultimate load was found as 150 KN. The maximum deflection at L/2 was found as 14.38mm and for 0.3% of sisal fibre RCC beam, the initial crack load was found as 110 KN, the ultimate load was found as 170 KN, and the maximum deflection at L/2 was found as 15.06 mm. The results are shown in figure 5.4

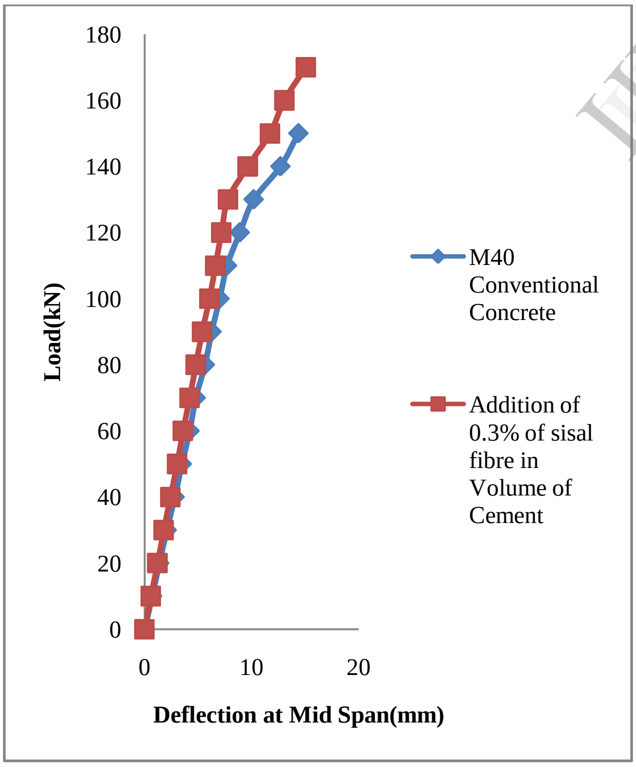

Fig 5.4 Comparison of Load Vs Deflection curve for M40 concrete and M40 concrete with 0.3% addition of sisal fibre in RCC beam

5.3.3 Modes of Failure

- All reinforced concrete beams failed in flexural zone.
- After the first crack load, the reinforcement started yielding and more number of cracks have formed in the flexural zone and extended towards the point loads with the increment in loads.
- At the ultimate load, the failure of all reinforced concrete beam occurred with crushing of concrete in compression zone.
- In control specimens are more number of cracks formed in flexural zone
- In SP3(0.3% sisal fibre) specimen are less number of cracks formed in flexural zone. It indicates the sisal fibre is contributing to the strength and stiffness of beam.

5.3.4 Flexural Behaviour of RCC Beams

The flexural behaviour of RCC beams for M40 grade concrete and M40 Concrete with 0.3% addition of sisal fibre in volume of cement were detailed in Table 5.13 Siffness at yield load and ultimate load, and deflection ductility were calculated and compared.

Table 5.13 Flexural Behavior of RCC Beams

S. No	Parameter	M40 RCC Reference concrete	M40 concrete adding 0.3% of sisal fibre in volume of cement
1	Initial crack load (kN)	90	110
2	Ultimate load (kN)	150	170
3	Ultimate deflection (mm)	14.38	15.06
4	Ductility Index	2.29	2.26
5	Stiffness value at initial crack load	14.35	16.61
6	Stiffness value at ultimate load	10.43	11.48
7	Percentage Reduction in Stiffness	27.33	32.06
8	Energy Absorption Capacity	564.3	728.2
9	Energy Ductility	3.82	3.91

6. CONCLUSION:

From the summary of this experimental work, the following conclusions were arrived,

The optimum percentage of sisal fibre for maximum strengths (compressive and split tensile) was found to be 0.3% for M40 grade of concrete.

- Modulus of rupture decreases with increase in percentage of sisal fibre.

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- Workability decreases with increase in percentage of sisal fibre.
- The flexural strength of concrete with optimum percentage of sisal fibre increases the strength when compared with the conventional concrete.
- The control specimen beam has nominally higher ductility index than SP 3 beams.
- The stiffness of SP3 specimen is higher than the control specimen. This shows that the SP3 specimen is stiffer than the control specimen. This stiffness reduces the deflection characteristics of the specimen.
- The energy ductility is higher for 0.3% of sisal fibre in volume of cement specimen. Thus the 0.3% of sisal fibre specimen improves the ductility performance of the concrete beam. The better ductility performance of SP3 due to the bonding between the steel and concrete was good.

7. SCOPE FOR FURTHER STUDIES

In this project the flexural behavior of beam using 0.3% of sisal fibre in volume of cement was carried out. Further work can be carried out

- By varying the percentage of sisal fibre and adding silica fume for the replacement of cement, their by durability of sisal fibre reinforced concrete can be increased.
- Study regarding the durability of sisal fibre in concrte can be made.

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