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Research Article

DEFLECTION IN RCC BEAM COVERED WITH SISAL CORDAGE

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ABSTRACT

The RCC structures show distressing signs within a span of only 6 to 10 years, whereas, the standard life of RCC frame structure is considered to be about 60 - 80 years. This can be recognized by number of reasons like non-maintenance, changed usage arrangement or initial inferior quality of construction. Such distressed beams often require strengthening. The most likely way to increase stability is to increase the strength of a structure. For strengthening the structural components, concrete jacketing and steel jacketing are the two general methods implemented. They are not only increase the cross sectional area and self-weight of the structure but also offer poor resistance to weather attacks. In the present paper, concept of covering of the beam with natural sisal fibres is assessed. Sisal fibres have strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. For present study, a RCC beam hinged at both the ends and subjected to point load at the center of beam is covered with sisal fibres and is analyzed using ANSYS software. The results are compared with analysis of beam without sisal fibres. This analysis results shows that, about 5 % decrease in deflection of beam by use of sisal fibres than normal.

KEY WORDS: RCC Beam, Sisal Cordage, Numerical Analysis, Deflection

INTRODUCTION

In India, generally residential and industrial structures are made of reinforced concrete. Usually, in major cases, the structures lack regular maintenance and thus show distress signs in a period of 6-10 years. Many times due to change of usage arrangement dictated by profitable demands requires strength up gradation of good structures. At times, aggressive environments deteriorate the structures. Inadequate performance of this type of structures is a major worry from public safety point of view. When these structural elements stop to provide satisfactory strength and serviceability, strengthening or upgrading becomes necessary. Conventional strengthening methods like concrete and steel jacketing prove to be expensive and elaborate. Further, these methods result in increase of dead weight, which is unwanted. Fibre reinforced cordage can be effectively used as an outer strengthening for upgrading such structurally deficient reinforced concrete structures, current research mainly focus on this aspect.

Numerous studies have been done in the area of strengthening of RCC beams with external bonded fibre reinforced plastic laminates and fabric. Recently, researchers have attempted to simulate the behavior of reinforced concrete strengthened with Fibre Reinforced Plastic composites using finite element method. Researchers have used finite element method to simulate behavior and failure mechanisms of RC beams strengthened with fibre reinforced plastic plates.

For strengthening of structures glass fibres are also used. About 22.3 million tons of glass fibres are produced globally on an annual basis [1]. Although glass fibre products have somewhat superior mechanical properties, their life cycle performance is very questionable. Manufacturing of these products not only consume huge energy but their disposal at the end of their life cycle is also very difficult since there is virtually no recycling option. Annual industrial crops grown for fibre, have the potential to supply enough renewable biomass for various bio-products. Thus, there is a good case in support of possible use of natural fibers in place of glass fibers.

The natural fibres like jute, coir, banana, hemp, ramie, sisal etc. are used as composites in structural up gradation are progressively increasing. Wood flour and other fibres are primarily used as fillers in thermoplastic decking, building materials, furniture & automotive components. Long agricultural fibres such as flax, sisal, kenaf, bast, hemp & jute are used as structural reinforcements in thermoplastic/thermoset composites as a replacement of glass fibre. Natural fibre composites can easily be recycled than glass or carbon composites. The usage of natural fibre composites is higher in Europe than other countries [2]. Advantages of Natural fibre composites components includes weight reduction of 10-30%, excellent acoustical absorption properties, good impact properties with convenience of forming complex shaped parts in a single molding process. Coir fibres have a diameter of 100 to 450 mm, density of 1.15 gm/cc, elastic modulus of 4 to 6 GN/m^2, an elongation percentage of 15 to 40 %, cellulose/Lignin content of 43/45 %, and micro fibrillar angle of 30 to 49 degrees [3]. The pre-treatment of fibres changes the composition and ultimately changes not only its properties but also the properties of composites. Some-times it improves the behavior of fibres but sometimes its effect is not favorable [4].

Using finite element analysis, an attempt has been made to study the behavior of sisal covered RCC beam and un-retrofitted reinforced concrete beam incorporated in this paper. The beam is subjected to point load at the center of span. Observations are made for reduction in deflection of Reinforced Concrete beam strengthened with FRSC (Fiber Reinforced Sisal Cordage). The finite elements software ANSYS is used for simulating RCC beam retrofitted using sisal cordage. The natural fibres like sisal, banana, wakka etc., are local resources which are easily available in and around the area in which structural elements are situated. Sisal fibre is derived from the leaves of the plant. It is usually obtained by machine decortications in which the leaf is crushed between rollers and then mechanically scraped. Sisal fibre is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs and resistance to deterioration in saltwater.

A relatively fresher concept is to consider natural fibres as a reinforcing material. Moreover, sisal banana leaf fibres are already available as products for consumer and industrial uses. Stringent environmental law and consumer awareness has forced industries to support long term sustainable growth and develop new technology based on renewable feedstock. The sisal plants look like giant pineapples, and during harvest the leaves are cut as close to the ground as possible. The soft tissue is scraped from the fibres by hand or machine. The fibres are dried and brushes remove the remaining dirt, resulting in a clean fibre. Sisal produces sturdy and strong fibres. Sisal fibre is one of the prospective reinforcing materials and its use has been more experiential than technical until now. The use of 0.2% volume fraction of 25mm sisal fibres leads to free plastic shrinkage reduction. Sisal fibres conditioned in a sodium hydroxide solution retained respectively 72.7% and 60.9% of their initial strength after 420 days. On immersion of the fibres in a calcium hydroxide solution, it was noticed that original strength was completely lost after 300 days [5].

The explanation for the higher attack by $Ca(OH)_2$ can be related to a crystallization of lime in the fibres pores is given by [6]. Presently, Sisal represents the first natural fibre in commercial application, in which it is estimated in more than half of the total of all natural fibres used. The Sisal plant is a monocotyledonous, whose roots are fibrous, emerging from the base of pseudo stem. As per [7], the fibres of sisal are made of elementary fibres of 4 to 12 μm diameter that are aggregated by natural bound forming small cells of 1 to 2 μm. Such arrays are placed along the length of the plant on a regular shape, with lengths of 45 to 160 cm. The composition of sisal leaves is basically of cellulose, lignin and hemicelluloses. The lignocellulosic material contributes to about75 to 80 % of the total weight of the leaves. While, cellulose contributes to about 9 to 12 % of the total weight. The failure strength and the modulus of elasticity, besides the lengthening of rupture, depends on the amount of cellulose and the orientation of the micro-fibres. As a natural product, these characteristics have a wide variation from one plant to another. The sisal cordage are found commercially in several formats: fabric, cords, strips, wire, rolls, etc. and available in countries like, East Africa, Bahamas, Antiqua, Kenya, Tanzania, and India. Various researchers provide the mechanical properties of sisal fiber which are as shown in Table 1. Properties of these sisal fibres used in this paper for modeling are as shown in Table 2.

Table 1: Mechanical Properties of Sisal Fibres

Tensile Strength (Mpa)	Tensile Modulus (Gpa)	Elongation at Break (%)	References
550±100	24 ± 0.4	2.4 ± 0.4	Oksman et al., 2002
400–700	7 – 20	2 – 14	
400–700	9 – 38	2 – 14	Li, Y., 2007
100–700	25 – 50	3 – 6	
400–700	9 – 20	5 – 14	Joseph et a.l, 2002
530–630	17 – 21	3 – 7	Jacob et al., 2006
434	17.5	-	Ganan et al., 2005
511–635	9.4 – 22	2 – 2.5	Shibata et al., 2003
500±70	13.2 ± 3.1	4.8±1.1	Gonzalez., 1999
450–700	7 – 13	4 – 9	Nair et al., 1996
511–700	3 – 98	2 – 2.5	Bogoeva et al., 2007
340±7	12.8	6 – 7	Idicula and Boudenne, 2006
501.3 ± 119.5	50.57 ± 3.27	0.78 ± 0.41	Saxena et al., 2011

[11], suggested advantages of sisal cordage are as follows. They are very well resistant against moisture. These fibres have a good tension resistance or tensile strength. Sisal short fibres delay restrained plastic shrinkage controlling crack development. Sisal fibres conditioned in a sodium hydroxide solution retained respectively 72.7% and 60.9% of their initial strength. A disadvantage of sisal cordage is its decomposition in alkaline environments or in biological attack. Applications of the sisal cordage are as follows.

Table 2: Properties of Sisal Cordage [4]

Item	Value
Density	1.33 g/cm^3
Poisson’s Ratio	0.3
Modulus of elasticity	5 x10^{10} Pa

It is mainly used for ropes, mats, carpets and concrete reinforcement. In developing countries, sisal fibres find wider use as reinforcement material in houses.

Geometry and Material Properties of Concrete

Almost all the structures exhibit a certain degree of nonlinearity at various load stages. This may be due to material nonlinearity or geometric nonlinearity. Geometric nonlinearity is associated with certain structures where large deflection may alter the configuration of the structure and affect the behavior of the structure on further loading. The effect of displacement on the internal forces must be considered in the analysis of such structures. However, in concrete structures, the displacements are small compared to the dimensions of the structure and hence in the present study geometric nonlinearity is neglected. Since concrete is a nonhomogeneous material and behaves linearly over only a small percentage of its strength, material non linearity is considered in our analysis. Nonlinear finite element analysis is a powerful tool in determining the internal stress strain distribution in concrete structures. With the aid of nonlinear finite element analysis it is possible to study the behavior of composite layered concrete frames up to the ultimate load range, which leads to the optimum design of the concrete frames. The load deformation relationships can be used to realistically predict the behavior of the structures. Nonlinear analysis gives better knowledge of serviceability and ultimate strength. The computational time and solution costs of nonlinear analysis are very high compared to linear analysis. Hence, the method should be as efficient as possible and the numerical technique adopted should reduce the computational requirements.

The finite element analysis approach is adopted considering the various material nonlinearities such as stress strain behavior of concrete, cracking of concrete, aggregate interlock at a crack, dowel action of the reinforcing steel crossing a crack etc. Composite layered concrete being a composite material by itself, numerical modeling of this is still an active area of research. Nonlinear finite element analysis based on advanced constitutive models can be used well for the simulation of composite layered concrete structures [19]. Computer simulation is a strong tool for checking the performance of concrete structures in design and development. Such simulation can be regarded as virtual testing and can be used to confirm and support the structural solutions with complex details and also serve to find an optimal and cost effective design solution. Hence, the aim of the present study is to conduct a finite element analysis for the computation of difference in deflection of RCC beam and the beam covered with sisal cordage. The properties of the RCC beam used in the present study are as shown in Table 3. The beam used has a cross section of 200 mm x 200 mm with an overall length of 1200 mm. M20 grade of concrete was used. Geometry of the reinforced cement concrete beam (RCC) and fibre reinforced sisal cordage (FRSC) beam are shown in Figure $1a_1$ and $1a_2$ and mesh diagram for the same are shown in Figure $1b_1$ and $1b_2$.

Table 3: Details of the RCC Model [3].

Item	**Value**
Compressive strength	20 N/mm^2
Young's modulus	3 x10^{10} Pa
Poisson's Ratio	0.2
Density	2.3 g/cm^3
Details of RCC Beam Dimensions	
Length of the RCC Beam	1200 mm
Width of the RCC Beam	200 mm
Depth of the RCC Beam	200 mm
Details of the Steel Reinforcements	
Longitudinal Bars at top	2 nos of 10mm dia each
Longitudinal Bars at bottom	2 nos of 10mm dia each
Stirrups	6 mm dia at 50 mm C/C.
Yield strength of these longitudinal & stirrup reinforcements	415 N/mm^2
Young's modulus of Steel	200000 N/mm^2
Poisson's Ratio of Steel	0.3
concrete cover for the reinforcements at top, bottom and sides	25 mm

The finite element mesh used in these analyses involved 8107 elements with 37392 nodes for RCC beam and 4280 elements with 25818 nodes for FRSC beam. The thickness of sisal cordage used for wrapping is 5 mm.

For present investigation, a beam hinged at both ends and subjected to centric point load is covered with sisal cordage and is analyzed using ANSYS software. The results are compared with analysis of beam without sisal cordage wrapping. A centric load is varied from 7 kN to 19 kN for both RCC and FRSC beam.

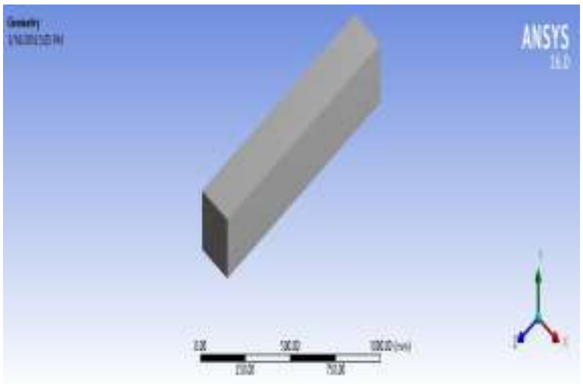

Figure $1a_1$: Geometry of Reinforced Concrete Beam & Sisal Covered RCC Beam

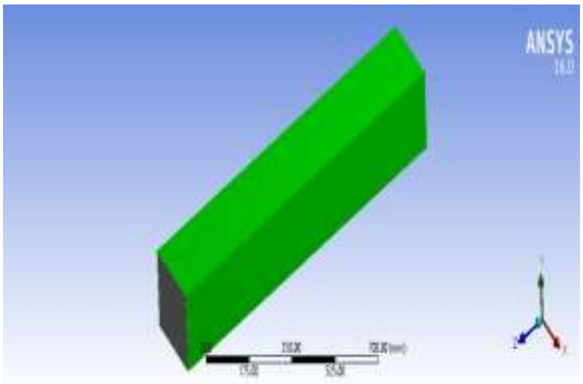

Figure $1a_2$: Geometry of Reinforced Concrete Beam & Sisal Covered FRSC Beam

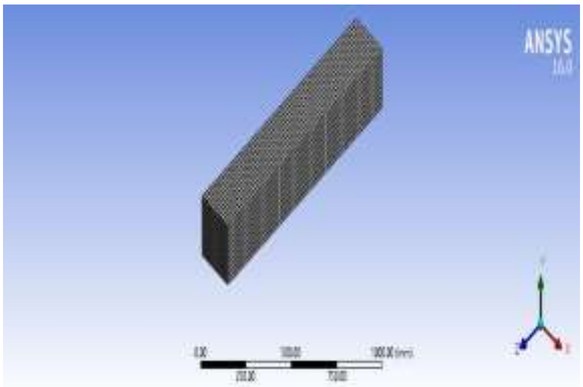

Figure 1b$_1$: Mesh Diagram of Reinforced Concrete Beam & Sisal Covered RCC Beam

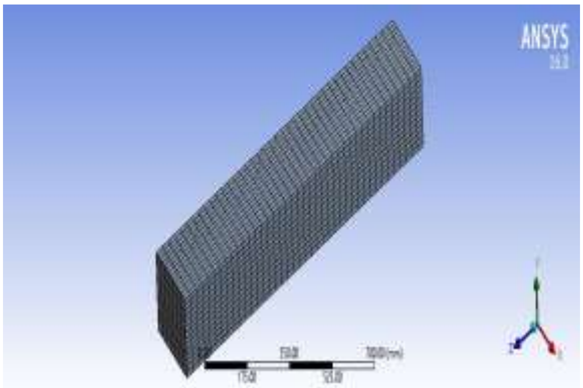

Figure 1b$_2$: Mesh Diagram of Reinforced Concrete Beam & Sisal Covered FRSC Beam

INVESTIGATIVE RESULTS

Among the numbers of load variations, comparison in deflection between RCC beam and FRSC beam has been shown in Figure 2a and 2b for 7 kN load and Figure 3a and 3b for 9 kN load only. Table 4 shows the deflection value of RCC beam and FRSC beam of sisal cordage for all load variation of 7 kN to 19 kN.

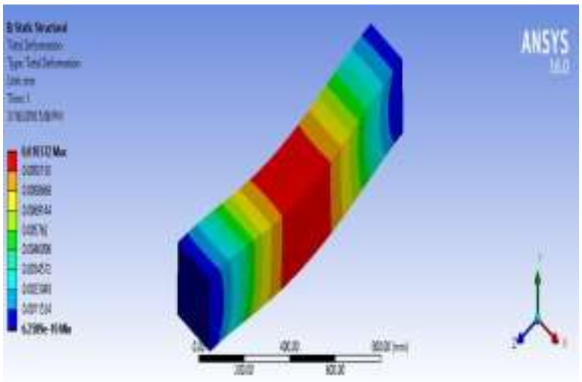

Figure 2a: Deflection for RCC Beam for 7 kN Load

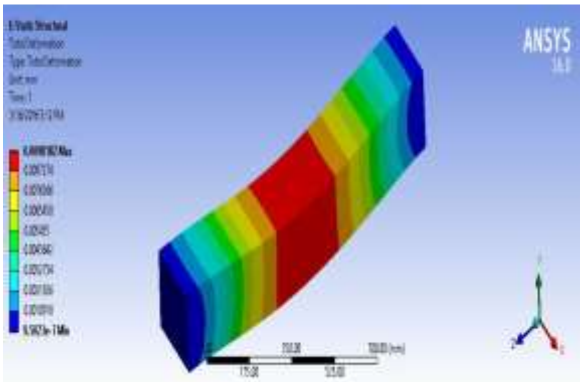

Figure 2b: Deflection for FRSC Beam for 7 kN Load

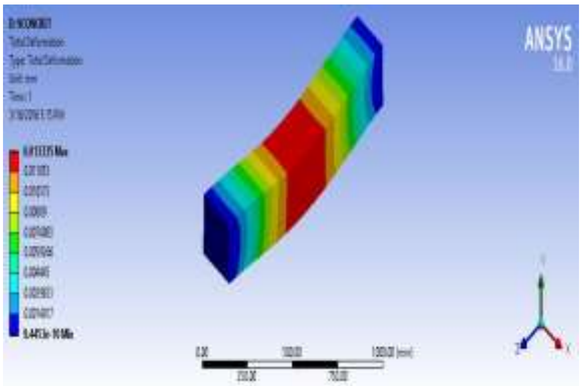

Figure 3a: Deflection for RCC Beam for 9 kN Load

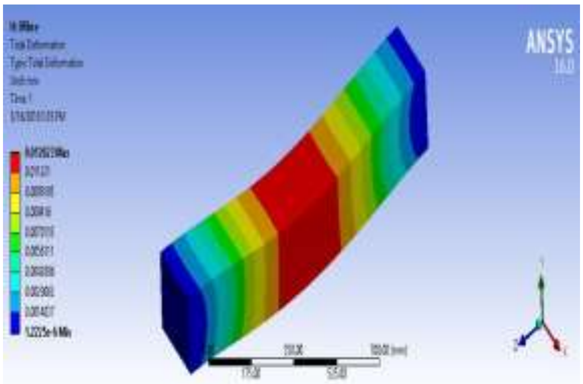

Figure 3b: Deflection for FRSC Beam for 9 kN Load

Table 4: Deflection Value of RCC and FRSC beam

Loading (kN)	Beam Type		% Decrease in Deflection
	RCC	FRSC	
	Deflection (mm)		
7	0.0103	0.0098	4.80
9	0.0133	0.0126	5.26
11	0.0163	0.0154	5.52
13	0.0193	0.0182	5.59
15	0.0222	0.0210	5.41
17	0.0252	0.0238	5.55
19	0.0282	0.0266	5.67

CONCLUSIONS

The following conclusive details have been obtained from the analytical results:

From the above results that FRSC beam of sisal cordage gives lesser deflection by about 5 %. From this, it follows that Moment capacity is also increased by about 5 % for the same cross section and span of the beam. Thus, deflection reduction clearly exhibits the increased strength of the beam. Undoubtedly, the method of strengthening is less expensive, easy to execute and environment friendly. This methodology will gain confidence of users and will find widespread applicability. A realistic study can be carried out experimentally to investigate the deflection in the beam.

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