Effect of addition of sisal fiber on the performance of the concrete beam

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Abstract:

The recent developments in the application of the advanced composites in the construction industry for concrete rehabilitation and strengthening are increasing on the basis of specific requirements. A numerical analysis has been carried out to investigate the performance of reinforced concrete beam structure with natural fiber (sisal fiber).The main aim of this investigation is find out the behavior of the sisal fibre in reinforced concrete beam structure against the different loading conditions with different percentage of sisal fibre. Using finite element analysis, an attempt has been made to study the behavior of sisal covered RCC beam incorporated in this work. The beam is subjected to a load at the center of span. Observations are made for reduction in deflection of Reinforced Concrete beam strengthened Fiber Reinforced Sisal fiber. The finite elements software ANSYS is used for simulating RCC beam with addition of sisal fiber. Three different loads were considered for the analysis. Two different composite beams with 4% and 8% of sisal fiber of total volume were compared with the plane concrete beam. The total deformation of the beam reduced with addition of the sisal fiber. The maximum principle stress has also been reduced with addition of the sisal fiber with around 30.46%.

Keywords: concrete, natural fiber, total deflection, sisal fiber, reinforced concrete.

1. Introduction

Concrete is used to build various civil engineering infrastructures such as skyscrapers, bridges, sidewalks, highways, houses and dams. Structural elements are often built with reinforced concrete. Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are change in their use, new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes. In such circumstances there are two possible solutions: replacement or retrofitting. Full structure replacement might have determinate disadvantages such as high costs for material and labour, a stronger environmental impact and inconvenience due to interruption of the function of the structure e.g. traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or fibre reinforced polymer (FRP) plates to the surface of the concrete. The plates then act compositely with the concrete and help to carry the loads. FRP can be convenient compared to steel for a number of reasons. These materials have higher ultimate strength and lower density than steel. Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. The addition of random fibres to concrete considerably improves its structural characteristics such as static flexural strength, impact strength, tensile strength, ductility and flexural toughness. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres each of which lend varying properties to the concrete. So many types of natural fibers are used as composite material in concrete structure such as sisal, jute, cotton, palm life, wood etc. Sisal fiber is type of leaf fiber. Leaf fibers are fibers make from leaf of tree tissues by machine scarping by retting process. The leaf fiber gives high strength as compare to other types of natural fibers. Sisal fibers are generally usage in yarns, ropes, twines cords, rugs, mattresses, and mat and handicraft materials. These Fibers have advantage of easily available, economical extraction, no hazard to environment and good tensile strength etc. Sisal Fiber is exceptionally durable with a low maintenance with minimal wear and tear. Sisal fibers are Antistatic, does not attract or trap dust particles and does not absorb moisture or water easily. It exhibits good sound and impact absorbing properties. Its leaves can be treated with natural borax for fire resistance properties. It is also surprisingly used as the fibre core of the steel wire cables of elevators, being used for lubrication and flexibility purposes. Traditionally sisal was the leading material for agricultural twine or baler twine. Although this has now been overtaken by polypropylene. It is also surprisingly used as the fibre core of the steel wire cables of elevators, being used for lubrication and flexibility purposes. Traditionally sisal was the leading material for agricultural twine or baler twine. Although this has now been overtaken by polypropylene. Investigation of the behaviour of FRP retrofitted reinforced concrete structures has in the last decade become a very important research field. In terms of experimental application several studies were performed to study the behaviour of retrofitted beams and how various parameters influence the behaviour. The effect of number of layers of CFRP on the behaviour of a strengthened RC beam was investigated by Toutanji et al. [4]. They tested simply supported beams with different numbers of CFRP layers. The specimens were subjected to a four-point bending test. The results showed that the load carrying capacity increases with an increased number of layers of carbon fibre sheets. Investigation of the effect of internal reinforcement ratio on the behaviour of strengthened beams has been performed by Esfahani et al. [5]. Specimens with different internal steel ratio were strengthened in flexure by CFRP sheets. The authors reported that the flexural strength and stiffness of the strengthened beams increased compared to the control specimens. With a large reinforcing ratio, they also found that failure of the strengthened beams occurred in either interfacial debonding induced by a flexural shear crack or interfacial debonding induced by a flexural crack. A test programme on retrofitted beams with shear deficiencies was done by Khalifa et al. [6]. The experimental results indicated that the contribution of externally bonded CFRP to the shear capacity of continuous RC beams is significant. Pawar et al. [7] Perform any research work, the preliminary preparation is necessary. Preliminary planning, procedures and methods wisely chosen and rigorously implemented. Monald et al. [8] did a analysis on basalt fibers allow to define composite materials really competitive with those obtained by employing traditional glass or carbon fibers. For instance, strengthening and retrofitting of existing structures (both concrete and masonry) may be performed through basalt-based fiber-reinforced polymers (BFRP) and cementitious matrices (BFRCM), as well as novel design concepts can be exploited by referring to basalt-based rebars and fiberreinforced concrete (BFRC). This paper aims to furnish a systematic review of the state of the art on basalt fibers, basalt-based composite materials and their applications in civil engineering field, by tracing main available evidence and highlighting perspective aspects and open problems. Anand et al. [9] presented 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. 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. Badshah et al. [10] a composite material can be defined as a macroscopic combination of two or more distinct materials, having a recognizable interface between them. This work comprises of fabrication of sisal fibre polymer composite material samples, followed by the testing of its mechanical properties. Products based on this work will be cheaper and sustainable. Natural fibres have the advantage that they are renewable resources. Obaidat et al. [11] presents the results of an experimental study to investigate the behaviour of structurally damaged full-scale reinforced concrete beams retrofitted with CFRP laminates in shear or in flexure. The main variables considered were the internal reinforcement ratio, position of retrofitting and the length of CFRP. Tara and Reddy 2011 [12] were conducted nonlinear finite element analysis in order to evaluate the performance of sisal fibers in structural retrofitting by retrofitting a Plain Concrete Block by using sisal fiber reinforced polymer. Results obtained from the simulation showed that the reinforced concrete beam retrofitted with sisal fiber using the full wrapping technique around all four sides, 83.33 % load carrying capacity were increased as compared to that of the controlled specimen. Models can be enhanced as compared to that of the controlled specimens by providing different percentage. The use of sisal fibres for retrofitting of reinforced concrete beams also minimizes the deflections in the beams. Tara and Reddy 2011 [13] were conducted a Finite Element Simulation of retrofitting of RCC beam using coir fiber composite (Natural Fiber). SOLID65 were used for the 3-D modeling of solids with or without reinforcing bars (rebar). From the obtained results it was reported that 83.33 % load carrying capacity was increased as compared to that of the controlled specimen when reinforced concrete beam were retrofitted with Coir fiber using the full wrapping technique around all four sides. Subramani and Senthilkumar 2016 [15] were studied Finite Element Analysis of RC beams with externally bonded Simcon laminates by using ANSYS. Also, carried out an experiment to compare analytical results. Results showed that SIMCON laminates properly bonded to the tension face of RC beams can enhance the flexural strength substantially. The strengthened beams exhibit an increase in flexural strength of 45.45 percent for laminates having volume fraction 5.5 percent and aspect ratio

300 and 400, 89.09 percent for volume fraction 5.5 and aspect ratio 400, and 100 percent for volume fraction 5.5 percent and aspect ratio 300.

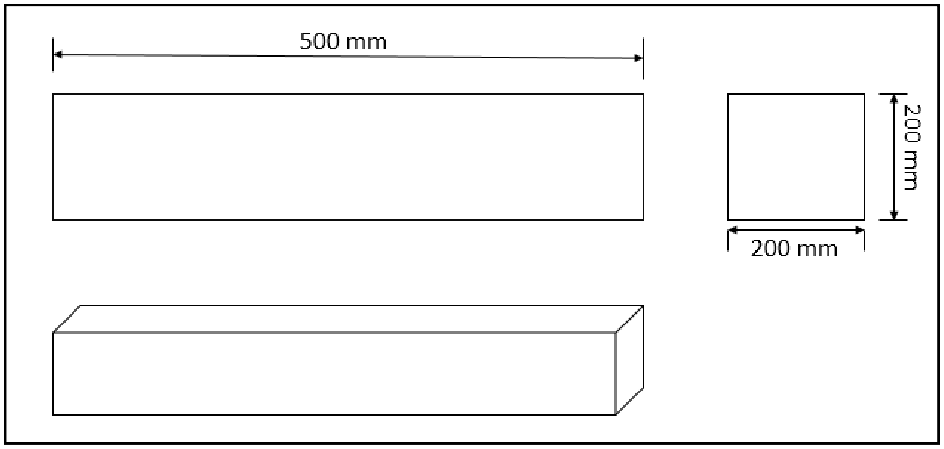
The main aim and scope of this investigation is find out the behavior of the sisal fibre in reinforced concrete beam structure against the different loading conditions with different percentage of sisal. Following are the main objectives behind this study. Using finite element analysis, an attempt has been made to study the behavior of sisal covered RCC beam incorporated in this work. The beam is subjected to point load at the center of span. Observations are made for reduction in deflection of Reinforced Concrete beam strengthene Fiber Reinforced Sisal fiber. The finite elements software ANSYS is used for simulating RCC beam with addition of sisal fiber.

2. Numerical Analysis

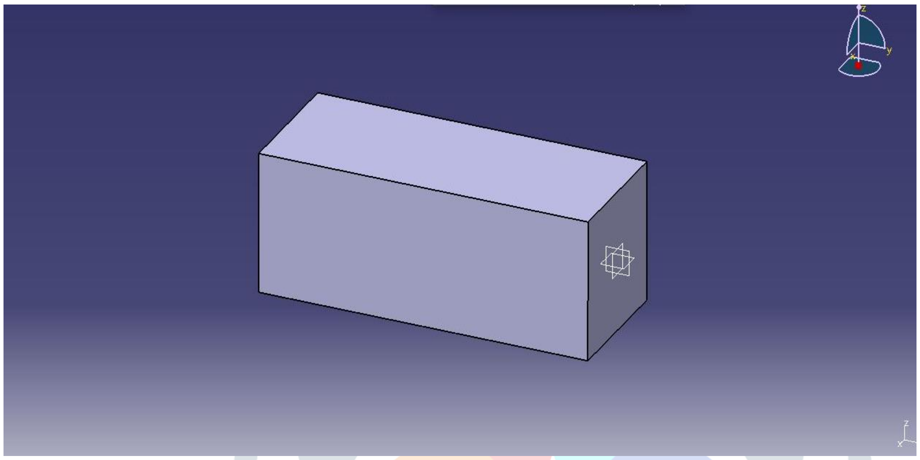
The main objective of the present section is the assessment of sisal fibre reinforced cement composite for the development of new constructive elements of semi-structural character. Taking advantage of the capabilities of existing advanced computer programs for the material nonlinear analysis of cement-based structures, this aim will be explored by selecting a software that integrates constitutive models prepared for the simulation of the nonlinear behaviour of fibre reinforced cement composites. An ANSYS ACP structural analysis computer program was used for the calculation of the stress and deflection of the composite material. An ANSYS ACP structural analysis is a computer code whose purpose is the analysis of structures by the FEM. In the context of finite-element material nonlinear analysis of concrete shell structures. Three different load were considered for the analysis . 1) 4 kN 2) 6 kN and 3) 8kN. The properties of the concrete has been seen in above table 4.1. Maximum shear stress were plotted for all three load cases. A sisal fiber material has been added into the concrete to improve the strength with the addition of 2% (0.58 kg) and 4% (1.16 kg) of the material.

2.1 Numerical domain

A numerical domain for the study of effect of sisal fiber on the stress analysis of the concrete is shown in figure 1 (a and b). A solid section of 200 width 200 thickness and 500 mm length has been consider for the analysis of each case with and without sisal fiber. The loading conditions for the simulations are also mentioned in figure 4.2. A uniformity distributed load (UDL) has beenuniformly distributed load (UDL) has been applied with 4 kN, 6 kN and 8 kN loading. The sides of the slab was considered to be fixed.



(a) Schematic of the numerical domain (geometry) considered for the analysis.



(b) numerical domain for analysis

Figure 1 a) schematic of the numerical domain, b) numerical domain drawn in CATIA model software

2.2 Boundary conditions and properties

The properties of the material considered for the numerical analysis is shown in table.

Table 4.1 Properties of Concrete:

Compressive strength	20 N/mm^2
Young modulus	22361 N/mm^2
Poisson ratio	0.3
Density	2400 Kg/m^3

Table 4.2 Physical properties of sisal fibre [15]

Sr. No.	Properties	Value
1	Density (g/cm^3)	1.45
2	Average tensile strength (N/mm^2)	1090
3	Elongation (%)	18.2
4	Water absorption (%)	76.7 %

The boundary conditions and the meshing model used for the analysis is shown in figure 2.

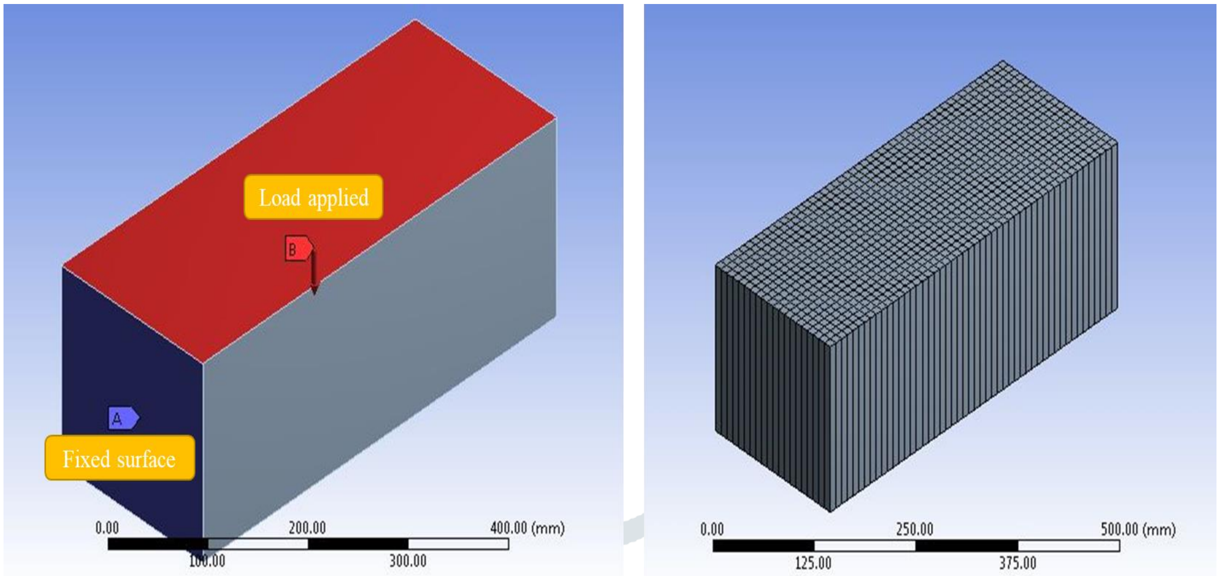


Figure 4.2 Boundary conditions and the mesh model used for the analysis.

3. Results and discussion

The sisal reinforced concrete beams with 200 mm x 200 mm x 500 mm was used in this study. The fiber content is used as variation for each specimen. Three different loading conditions (4, 6 and 8 kN) were considered for the analysis. A sisal fiber material with 4% and 8% of the total volume quantity was considered for the analysis. A total deformation and maximum shear stress has been calculated for the raw data and analysis done. The results obtained is mentioned in the following section.

3.1 Effect of sisal fiber on Maximum principle stress

A maximum principle stress was calculated for three different conditions of sisal fiber and concrete fiber material. 4% and 8% sisal fiber of the total volume of the composite can be added into the full concrete slab to enhance their strength. Figure 2 shows the graph of maximum principle stress with plain and composite for three different loading conditions. It is clear that, the maximum principle stress was found for plain concrete slab than the composite slab for all loading conditions. The maximum shear stress of 0.78 kN/m^2 was found for the plain concrete slab and 8kN loading conditions. The nature of the graph shows that, as the sisal fiber material added into the plain concrete slab the maximum principle stress can be reduced significantly. Up to a 60% of reduction in maximum principle stress can be found in all case with the addition of the sisal fiber material with 4 and 8% quantity. It is interesting to note that, there is a marginal reduction of the maximum principle stress when the sisal fiber material added from 4% to 85 quantity. The lowest maximum principle stress was found for 8% sisal fiber material.

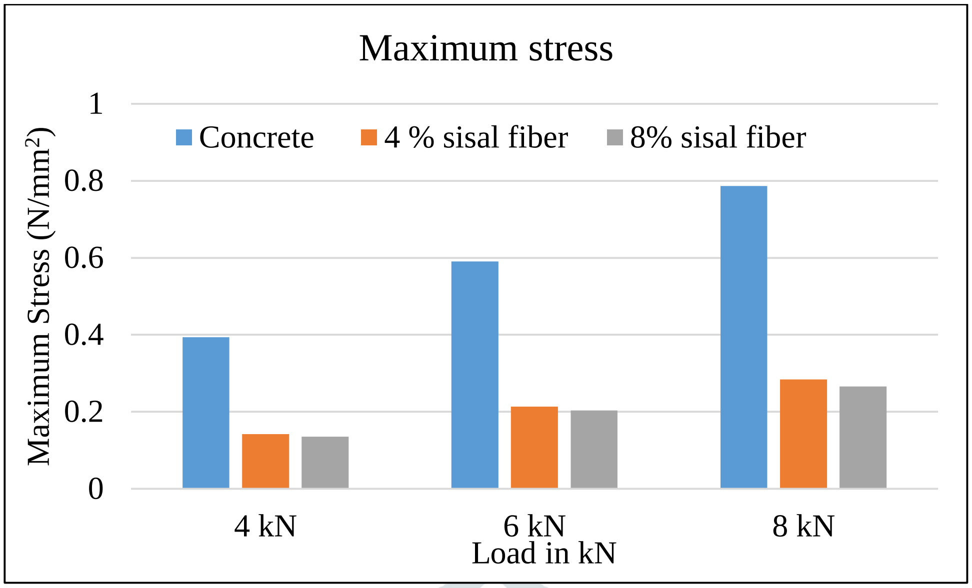
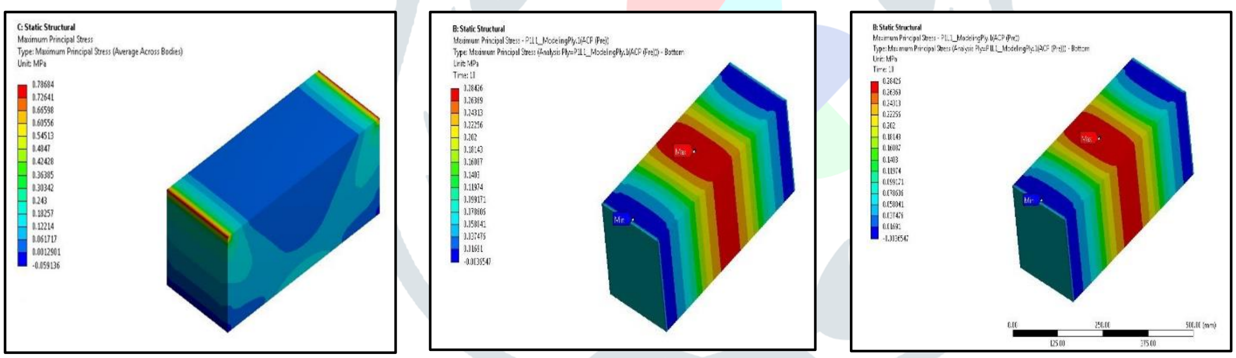


Figure 2 Effect of addition of the sisal fiber on the maximum stress

Figure 3 shows the contours maximum principle stress for the three different concrete compositions and for the 8kN loading conditions. A constant uniformly distributed load has been applied. It is interesting to note that, the maximum stress was found for the plain concrete material and top end corner of the slab. The principle stress for the case of sisal fiber composite was found maximum at the center of the slab.



(a) Plane concrete (b) 4% sisal fiber (c) 8% sisal fiber

Figure 3 Effect of addition of sisal fiber on maximum principal stress

3.2 Effect of sisal fiber on the total deflection RCC

A total deflection of the slab was calculated for three different conditions of sisal fiber and concrete fiber material. 4% and 8% of sisal fiber of the total volume of the composite can be added into the full concrete slab to enhance their strength. Figure 4 shows the graph of total deflection with plain and composite for three different loading conditions. It is clearly seen that, the total deflection of the beam was found maximum for plain concrete slab beam than the composite beam. A 0.00197 mm of the deflection was found for the 8 kN load for plain concrete slab beam. In case of 4 kN load the maximum deflection was found 0.00098 mm.

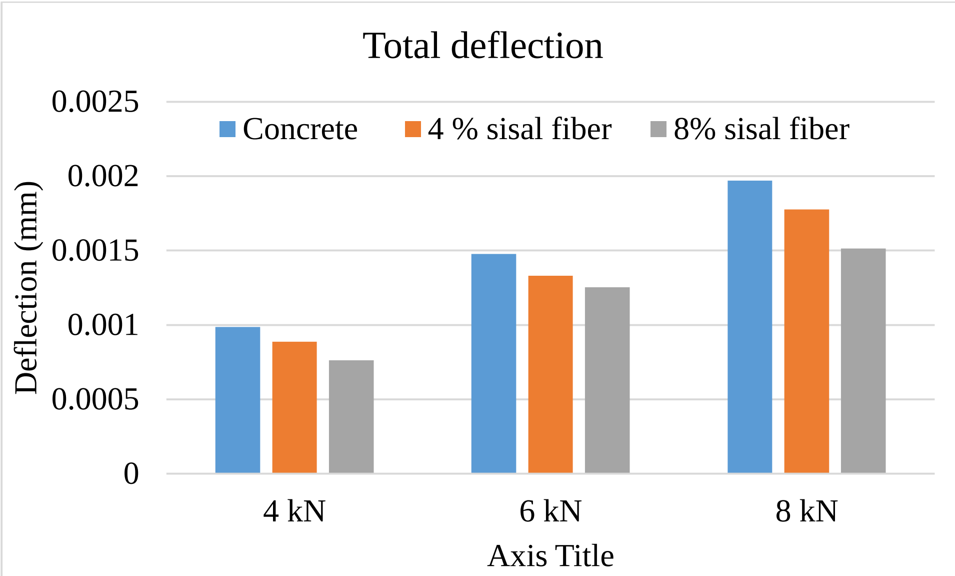
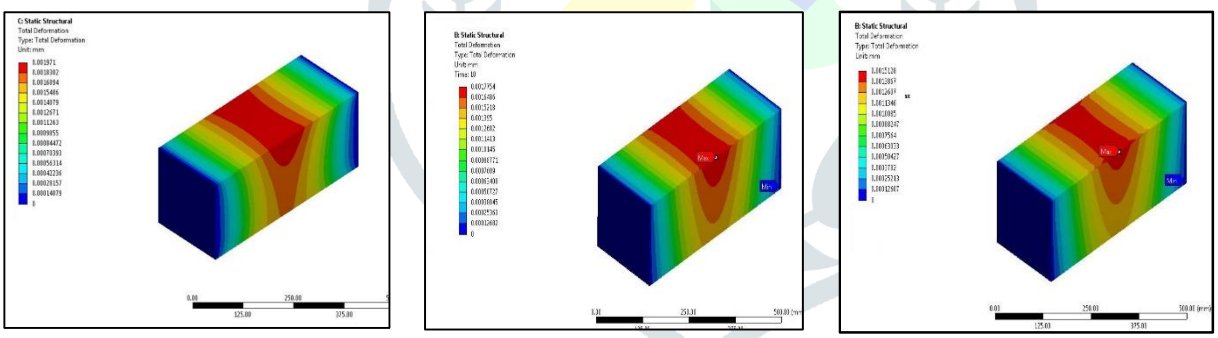


Figure 4 Effect of addition of the sisal fiber on the total deflection.

A deflection contours has been plotted for plane concrete beam and concrete beam with 4% and 8% sisal fiber. A deflection can be seen maximum at the center of the beam. It is noted that, the maximum total deflection of the beam was reduced with the addition of the sisal fiber at the same location for each beam (center red colors for every conditions can explain these things). From the figure 5 it can be says that, the minimum deflection was seen at the end corner of the beam. The total deformation of 30.46% at 8 kN load can be reduced with the addition of the sisal fiber with 8%. Figure 5 shows the deflection contours for different percentage of sisal fiber.

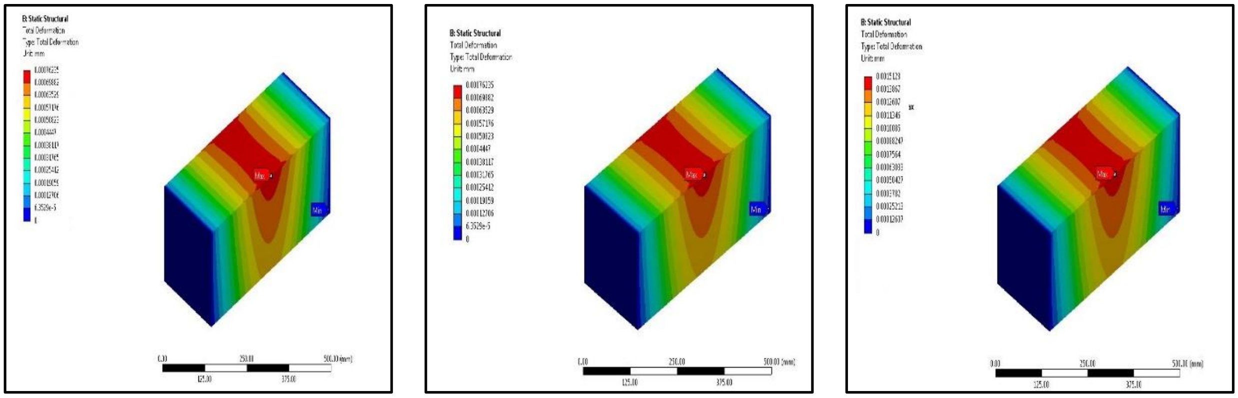


(a) Plane concrete (b) 4% sisal fiber (c) 8% sisal fiber

Figure 5 Effect of addition of sisal fiber on total deformation

3.3 Effect of increase in load with sisal fiber composite

The effect of increase in load can be investigated with change in different loading conditions on the of the 8% sisal fiber concrete slab beam. A 2, 4 and 8 kN load can be applied on the 8% sisal fiber composite concrete slab and the results investigated. The maximum deformation can be found for 8 kN loading conditions. It is noted that, the deflection of the beam increases with increase in loading conditions. Figure 6 shows the maximum principal stress for different loading conditions. The maximum stress can be calculated for different loading conditions for 8% sisal fiber composite beam. The maximum stress can be found for 8 kN load.



(a) 4 kN load (b) 6 kN load (c) 8 kN load

Figure 6. Contours of total deformation of composite slab beam with 8% sisal fiber and different loading conditions.

4. Conclusion

A numerical analysis has been done using FEA method to investigate the performance of composite concrete beam with sisal fiber material. A sisal fiber material was used to enhance the capacity of the plane concrete beam. A two combinations of the beam was compared with the plane concreate beam. A central load of 4, 6 and 10 kN was applied on the top surface of the beam. A total deformation, principle stress was studied with different loading conditions. The sides of the beam to be fixed for the analysis and the results has been plotted. A following conclusion has been drawn,

(a) The use of natural fibers, as reinforcement of composites (such as cement paste, mortar and/ or concrete), are economical for increasing their certain properties; for example, tensile strength, shear strength, toughness and/or combination of these.

(b) The total deformation of the beam reduced with addition of the sisal fiber. A total of around 60% reduction in total deformation was found with addition of 8% sisal fiber in total volume of concrete.

(c) The maximum principle stress has also been reduced with addition of the sisal fiber with around 30.46%.

(d) The deflection and the stress was found to be reduced with increase in loading conditions.

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