Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268 (Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 21 No. 1 pp.289-295 2022
Original Research Paper
https://doi.org/10.46488/NEPT.2022.v21i01.034
Open Access Journal

Effect of Surface Modification on the Characteristics of Sisal Fiber Reinforced Concrete Treated with Na_2CO_3

R. Abirami† and S. P. Sangeetha
Department of Civil Engineering, Aarupadai Veedu Institute of Technology, Vinayaka Missions Research Foundation, Chennai, T.N., India
†Corresponding author: R. Abirami; abirami.civil@avit.ac.in; abirajan26@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 09-06-2021
Revised: 02-07-2021
Accepted: 14-07-2021

Key Words:
Aspect ratio
Sisal fiber
Green technology
Material characteristics
Volume fraction

ABSTRACT

Concrete with fiber as a reinforcing material is one of the important fields of research that is gaining traction in this upcoming green technology revolution. By adding fibers to concrete, the tensile strength properties are vastly improved without compromising the strength characteristics, and cost fluctuation is minimal. This research is being carried out to improve the qualities of concrete that have been infused with chemically treated sisal fiber in varied ratios. The paper investigates and describes the effects of sisal fiber when it is chemically treated and infused with concrete, comparing it to ordinary concrete in strength tests. Water absorption, workability, and other material characteristics of Sisal fiber reinforced concrete with 0.5 per cent, 1 per cent, 1.5 per cent, and 2 per cent fiber replacing cement by volume fraction and a sisal fiber aspect ratio of 1:100 are compared to the traditional M30 concrete grade. After being treated with an alkaline solution, 0.5 per cent and 1 per cent sisal fiber reinforced concrete increased tensile and compressive strength, as well as the formation of calcium carbonate deposits on the fiber interfaces; this also contributes to the concrete's corrosion resistance and durability.

INTRODUCTION

Natural fibers are biodegradable and are extensively being used in new generation concrete technologies. For the past 20 years, this technology is being tested and developed. There is a conclusive result of all the experiments stating that adding natural fibers such as sisal, coir, hemp, Kenaf, pineapple fiber will be used as reinforcement and will provide better strength qualities (Jitendra et al. 2016). In addition, they also provide better insulation against electrical and thermal objects and have acoustic effects (Wei & Meyer 2014). Fibers in general are added to reduce the plastic shrinkage and drying shrinkage that occurs during formation. They can also reduce water draining in concretes by decreasing permeability (Silva et al. 2008). There are fibers that can improve the impact, shatter resistance, and abrasion of concrete. By adjusting the aspect ratio of the fiber, the tension strength of the material can be modified (Naresh et al. 2017). Sisal fiber is the object of interest in the following study conducted and tabulated in the paper. The characteristics of sisal fiber differ based on the manufacturing process, the age of the plant, the location, and other factors. Sisal fiber may be reinforced in a variety of ways because it is a surplus by-product from the agriculture sector and hence inexpensive, and it can be reused to avoid sending it to landfills. Sisal fiber is high in tension and low in density, hence many studies were conducted to understand its effectiveness and its application in concrete structural material (Abirami et al. 2020). The value fluctuates between experimental specimens due to the heterogeneity in the size of naturally available sisal fibers. However, the evidence is conclusive and gives a one-sided result when it comes to the usage of sisal fibers in concrete. (Sabarish et al. 2017).

Moisture absorption is a significant concern in natural fiber. The natural fiber's water content causes poor bonding between the fiber and the matrix (Melkamu et al 2018). Typically, fiber treatment is used to address this problem. Researchers usually use two separate fiber treatment methods such as thermal treatment and chemical treatment. Chemical treatments include alkaline treatment, acidic treatment, and benzolyzation. Natural fiber composites may reduce strength and durability as a result of fiber weakening caused by the combination of alkaline attack and crystallization caused by the migration of hydrogen products to lumens and spaces (Okeola et al. 2018, Ozerkan et al. 2016).

The aspect ratio of the test specimen height (h) to diameter (d) ratio is essential for loading for the sake of confinement effects. When the strength of concrete of cubes and cylinders with identical aspect ratios is studied, the correction factor rises as the aspect ratio rises (Hamad 2017). A higher aspect ratio means less isolation when it comes to a single specimen. Assuming the amount of slope utilized is equal to 4, a cylindrical sample having a specific aspect ratio of 2 will sustain less load than a cylindrical sample with a ratio of 1. Another component is fiber dispersion; less fiber dispersion results in a loose bundle with a lower aspect ratio and thus less reinforcing power than a single fiber. Furthermore, due to poor adhesion, the bundle itself may be weak. Any of the above factors minimize the composite's overall power (Sangeetha & Joanna 2014). Additionally, fiber bundles serve as stress transfer barriers, as a result, they have impaired properties. The presence of a powerful interface also influences the production of strength in a composite (Ghorpade & Sudarsanarao 2010).

Mwaikambo & Ansell (2006) had experimented with alkali-treated sisal fibers and examined the changes in internal structure and diameter, like cellulose material, micro-fibril angle, and crystallinity index. Alkalization was observed to affect the microstructure of sisal fibers, which had the same specific stiffness as steel. It's been found that alkali treatment is used to strengthen the crystalline quality of treated fibers, by altering the structure of sisal fiber to compete with the synthetic fibers.

The results of the treatment methods used in sisal fiber to make it corrosion resistant in alkaline concrete environments, as well as the toughness of the natural fiber being reinforced in the concrete in hostile situations, are described in this study.

Alkaline treatment is a technique for treating fiber with an alkaline solution, usually Na_2CO_3 or NaOH (Bjork & Carl 2002). The alkaline solution eliminates the active polar group of the fiber, removes moisture from the fiber, and improves the bonding between the fiber and matrix (Mithun et al. 2019).

MATERIALS AND METHODS

PPC cement that meets Indian standard IS 1489 (Part 2): 1991 is used in this present study. The characteristics of PPC cement were tested in the laboratory.

Manufactured sand is a rock that has been crushed to the proper grain size distribution (M- sand). The crushed materials are crushed in a specific rock crusher to obtain the necessary grain size, and the portion of the crushed materials is washed to extract fines. As fines aggregate, M-sand was used. As a result, the consistency and longevity of concrete have improved. The aggregate size passing through a 20 mm sieve was used as coarse aggregate for this work as per grading requirements.

Sodium Carbonate Solution

To soak the dry fiber, a Na_2CO_3 solution was used to take advantage of sisal fiber's water absorption (Fig. 1). After ten days in a saturated solution, a considerable amount of sodium ions and carbonate ions will accumulate on the fiber surface. When fibers are added to a concrete mixture, the Ca2+ in the cement causes chemical reactions on the fiber surface.

Sisal Fiber

Agava sisilana is the botanical name for sisal fiber. The material is primarily used in the production of rope for use in the marine and construction industries. Because of its inexpensive cost, lightweight, tensile strength and elastic modulus, low health risk, widespread availability in several places, and environmental friendliness, sisal fiber promises to be a cement composite with adequate natural reinforcement. This fiber was chosen for the current study because it has a high strength relative to other fiber materials. As indicated in the pictures Fig. 2 & Fig. 3 every fiber is layered, with a thin primary wall (the initial layer generated during cell development) enclosing a secondary wall. The intermediate

Fig. 1: Sodium carbonate.

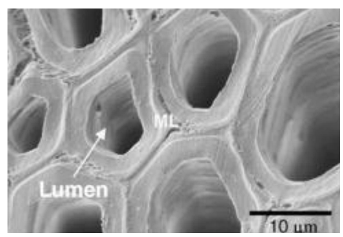

Fig. 2: Sisal fiber cell wall arrangement.

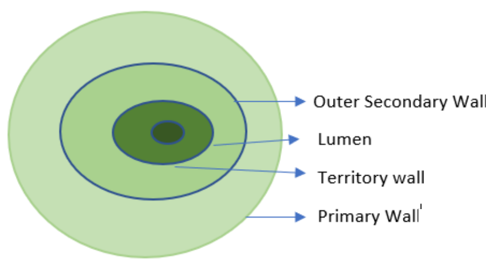

Fig. 3: Sisal fiber cell wall arrangement.

wall consists of three layers, the thickest of which influences the mechanical properties of the fiber. The intermediate layer consists of thin-walled wrapped cellular microfibrillar consisting of long-chain cellulose molecules. The microfibrillar angle is the angle formed by the fiber axis and the microfibrils. The cellulose angle's characteristic value varies from fiber to fiber. Because hemicelluloses and lignin in the center lamellae of fibers and celluloid particles have low corrosion resistance, they lose their capacity to strengthen the cement matrix later in its service life. To increase sisal fiber degradation resistance in alkaline environments alkaline solutions were used to partially extract lignin, cellulose, and hemicellulose as well as other residues from the surface of the fiber.

In this study, a dried and slightly processed sisal fiber with no knots or other impurities was employed. These fibers had a moisture content of 11.5%. Sisal fiber is made up of cellulose, hemicelluloses, lignin, and waxes. Sisal Fiber selected for this project contains cellulose (64%), hemicellulose (12.2%), lignin (10%), waxes (2%). Characteristic value and mechanical properties of sisal fiber are summarised in Table 1 and Fig. 4 represent fresh sisal fiber.

Casting of Specimens

Na_2CO_3 treatment: A Na_2CO_3 solution was used to soak the dry fiber, taking advantage of sisal fiber's water absorption. After several days of treatment in a Na_2CO_3 solution, the number of Na^+ and CO_3^{2-} ions accumulated on the fiber's surface would rapidly increase. When fresh concrete is applied to the fiber surface, a chemical reaction occurs as a result of the Ca^{2+} in the cement. The following chemical reaction is the primary cause of concrete alkalinity:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$$

To protect the inside of the fiber from the strong alkali solution formed during the cement hydration process, a coating of calcium carbonate sediments was created and poured into pits and holes on the surface of the sisal fiber.

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3\downarrow$$

Concrete's alkalinity prevents ionization of the particles, allowing the outer layer to last for a long period of time. The alkaline pore solution successfully resists the dissolving of hemicellulose and lignin found in the intermediate lamellae of the fibers, as well as cellulose molecule hydrolysis.

Basic material studies were carried out on cement, fine aggregates, coarse aggregates, and fibers. The M30 grade concrete is designed utilizing the IS10262-2009 material test values for cement in M-Sand, coarse aggregate, and sisal fiber using norm IS10262-2009. To effectively increase their degradation resistance, sisal fibers are soaked in Na_2CO_3 solution for 10 days, with varying percentages of sodium carbonate treated sisal fibers, such as 0%, 0.50, 1.00, 1.50, and 2.0%, as shown in Figs. 5 and 6. Cubes and cylinders are cast for seven, fourteen, and twenty-eight days, respectively. Based on compressive and tensile strength, we will establish the optimal dosage of Na_2CO_3 to be treated with sisal fibers.

Mix Proportion

According to IS 10262-2009, the mix was formulated to have a characteristic compressive strength of 30N.mm^{-2}. Based on the mix design, the cement content was determined to be

Table 1: Physical property of sisal fiber.

Fiber Property	Results
Fiber Diameter, mm	0.3-05
Fiber Length, mm	35-40
Aspect Ratio	1 in 100
Density, g.cm^{-3}	1.33
Tensile Strength, N.mm^{-2}	400 -700 MPa
%age of Elongation	13.5%
Young Modulus	9.4-22

Fig. 4: Sisal fiber.

387 kg.m^{-3}. In this analysis, the water-cement ratio was set at 0.42, and Gallium, Superplasticiser was used. Table 2 shows the specifics of the blend proportion and content quantity.

For both natural and sisal fiber reinforced concrete, cubes of 150mm × 150mm × 150mm, cylinders of 150mm diameter, and cylinders of 300mm height are cast at M30 grade concrete. Water curing is an important part of the cement concrete strength-building process. For the method depicted in Fig. 7, the concrete mix specimens were cured in the storage tank for 7, 14, and 28 days.

RESULTS AND DISCUSSION

The Impact of Sisal Fiber on Concrete Workability

In this project, the design technique was to keep all variables constant while adding sisal fibers in intervals of 0.5 per

Table 2: Mix proportion.

Components	Quantity [kg.m^{-3}]
Cement	387
M-Sand	740
Coarse aggregate	1206
Water	162.3

Table 3: Percentage of reduction in slump and compaction factor.

Fiber %age	Slump	% Reduction in a slump	Compaction factor	% of Reduction in compaction factor
0%	95	0	0.94	0
0.5%	72	21.73	0.91	3.19
1%	65	31.57	0.87	7.44
1.5%	58	38.94	0.82	12.76
2% fiber	34	64.21	0.80	14.89

Fig.5: Sisal fiber immersed in Na_2CO_3 solution.

Fig. 6: After 10 days fiber immersed in Na_2CO_3.

Fig. 7: Casting and curing of specimens.

cent by weight of cement. Table 3 shows the slump test and compaction factor results, as well as the overall slump value and compaction factor values with each combination based on the proportion of sisal fiber applied**.**

The workability of fresh sisal fiber reinforced concrete decreased overall, as evidenced by decreases in a slump and compaction factor values as the per centage of sisal fibers in the mix grew, and with a constant w/c of 0.42 utilized in the mix design.

Moisture Content Test on Sisal Fiber Reinforced Concrete

The moisture content of concrete is an indirect way of analyzing the pore structure and durability efficiency in a corrosive setting. Fig. 8 shows the moisture content of sisal fiber reinforced concrete in this analysis. The results show that reinforcing concrete with sisal fibers significantly increases the moisture content of the concrete. By adding 0.5 per cent sisal fiber, concrete absorption increased by 1.3 per cent after 28 days. Furthermore, incremental additions of 0.5 per cent sisal fiber resulted in minor improvement until a total of 2 per cent sisal fiber was added to the mix, resulting in an 11.5 per cent increase in water absorption above normal concrete.

Compression Test

Concrete cubes measuring 150mmX150mmX150mm are cast to test the compressive power. Specimens are cured for 7, 14, and 28 days at room temperature. Ultimate load (N) is considered at the point at which the specimen fails, and the cross-section of the specimen is known. Table 4 summarises the compressive strength results.

Na_2CO_3 sisal fibers are mixed with concrete in percentages of 0 per cent, 0.5 per cent, 1 per cent, 1.5 per cent, and 2 per cent, then cured for 7, 14, and 28 days to determine the compressive strength of sisal fiber reinforced concrete. Table 4 is depicted in Fig. 9 as a visual representation of the data. According to the experimental results, increasing the fiber content in concrete increases the compressive strength by up to 1%, while increasing the fiber content further reduces the concrete's strength.

Split Tensile Test

Casted cylinders of 150mm diameter (D) and 300mm height (H) are used for these tests. These specimens are mounted horizontally in between the compression testing machine's plates, and the maximum load (P) at which the specimen fails

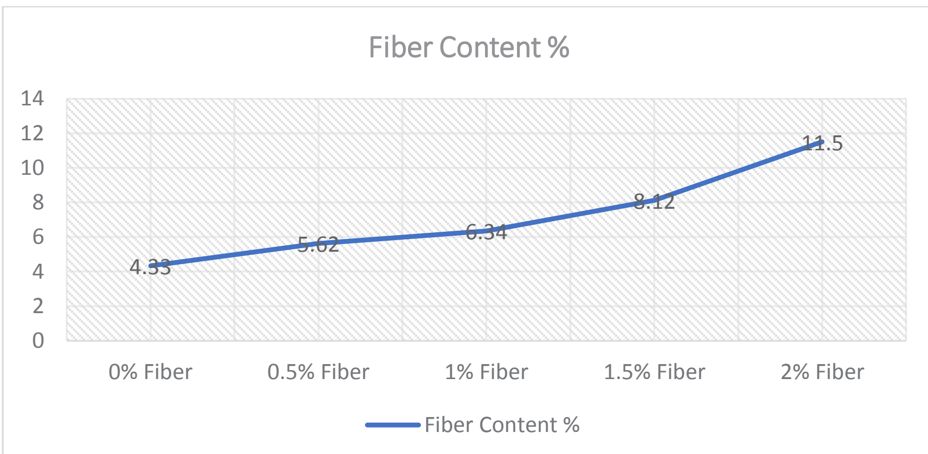

Fig. 8: Moisture content percentage of concrete.

Table 4: Compressive strength test.

S. No.	Fiber %age	Compressive strength $N.mm^{-2}$		
		7 days	14 days	28 days
1	0%	13.28	25.86	32.75
2	0.5%	14.78	28.07	34.15
3	1%	17.29	29.14	35.17
4	1.5%	16.26	28.64	33.10
5	2%	16.01	27.17	32.15

is reported, as well as the tensile strength values, which are tabulated in Table 5.

According to the test observations, the tensile strength of M30 grade concrete at the ages of 7, 14, and 28 days is represented in the above bar map. Fig. 10 depicts a graphical representation of the data in Table 5. The tensile strength of the concrete improves gradually until it reaches 1%, after which it tends to decrease as the fiber concentration increases.

CONCLUSION

Natural fibers are being reviewed as a potential substitute for synthetic fiber in the fiber/polymer composites materials industry. But in terms of environmental impact, cost of production, and biodegradability natural fibers have a huge advantage.

The effects of sodium carbonate processed sisal fibers on the characteristics of normal concrete, such as strength,

Table 5: Overall results of tensile strength values.

S. No.	Fiber %age	Tensile strength N.mm^{-2}		
		7 days	14 days	28 days
1	0%	2.03	2.56	2.78
2	0.5%	2.15	2.62	2.96
3	1%	2.24	2.74	3.12
4	1.5%	2.22	2.68	2.85
5	2%	2.12	2.52	2.74

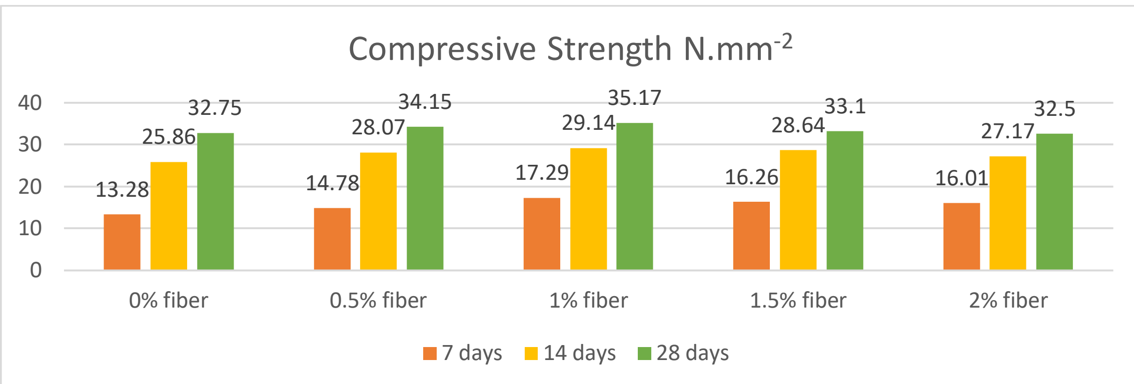

Fig. 9: The results of the compressive strength test.

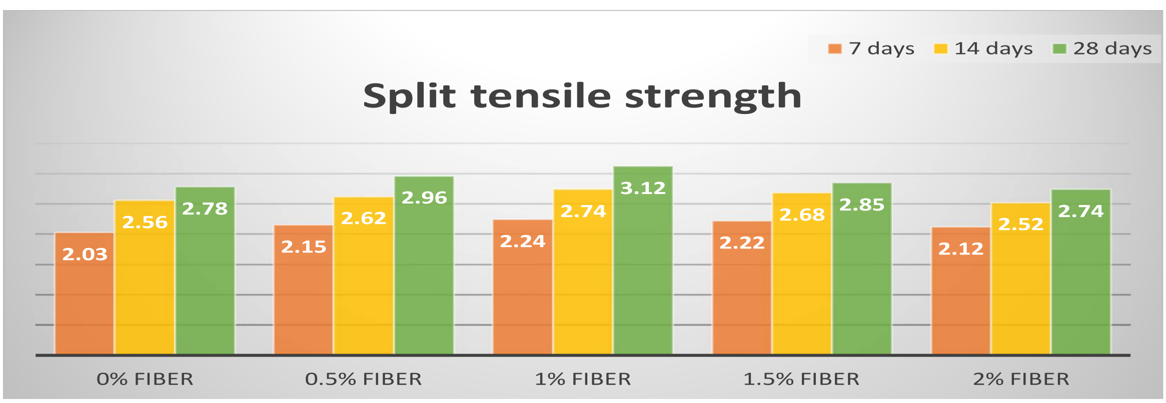

Fig. 10: The results of a tensile strength test.

were studied and tabulated using IS10262-2009 and varied per centages up to 2% for M30 grade concrete used for construction. Based on the findings, 1% sodium carbonate treatment of fibers added to concrete increases the concrete's compression strength by 3.5%.

The compressive and tensile strength of sisal fiber reinforced concrete will increase when 0.5 and 1% of fiber content are added. As 1.5 to 2% sisal fiber is added, the strength decreases. In addition to the increase in strength, it was discovered that this rise is due to the production of calcium carbonate deposits on the fiber interfaces as a result of being treated with an alkaline solution, which also improves the concrete's corrosion resistance and durability.

REFERENCES

Abirami, R., Sangeetha, S.P., Nadeemmishab, K., Yasirvaseem, P. and SuhailSad, K. 2020. Experimental behavior of sisal and kenaf fiber reinforced concrete. AIP Conf. Proc., 2271: 030023.

Bjork, F. and Carl, A.E. 2002. Measurement of alkalinity in concrete by a simple procedure, to investigate the transport of alkaline material from the concrete slab to a self-leveling screed. Constr. Build. Mater., 16: 535-542.

Ghorpade, V.G. and Sudarsanarao, H. 2010. Strength and permeability characteristics of fiber-reinforced recycled aggregate concrete with different fibers. Nat. Environ. Pollut. Technol., 9(1): 179-188.

Hamad, A.J. 2017. Size and shape effect of specimen on the compressive strength of HPLWFC reinforced with glass fibers' J. King Saud. Univ. Eng. Sci., 29(4): 373-380.

Jitendra, D., Kalwane, U. and Pallavi, P. 2016. Effect of fiber length and per centage of sisal on strength of concrete. Multidiscip. J. Res. Eng. Technol., 3(1): 923-932.

Melkamu, A., Kahsay, M.B. and Tesfay, A.G. 2018. Mechanical and water-absorption properties of sisal fiber (Agave sisalana)-reinforced polyester composite. J. Nat Fibers., 14: 877-885.

Mithun, K., Gowda, R.M. and Phulara, S.C. 2019. A study on structural characteristics of sisal fiber reinforced concrete. Int. J. Eng. Res., 8(06): 616-636.

Mwaikambo, L.Y. and Ansell, M.P. 2006. Mechanical properties of alkali-treated plant fibers and their properties. J. Mater. Sci., 41: 2497-2508.

Naresh, J., Nalin Pandian, T. and Priyavadhani, S. 2019. Study on the result of the implementation of sisal fiber in reinforced cement concrete. Int. Res. J. Eng. Technol., 06(04): 51-79.

Okeola, A.A., Abuodha, S.O. and Mwero, J. 2018. The effect of specimen shape on the mechanical properties of sisal fiber-reinforced concrete. Open. Civ. Eng. J., 12(01): 368-382

Ozerkan, N.G., Tokgoz, D.D.G., Kowita, O.S. and Antony, S.J. 2016. Assessment of microstructural and mechanical properties of hybrid fibrous self-consolidating concretes using ingredients of plastic waste. Nat. Environ. Pollut. Technol., 15(04): 1161-1168.

Silva, F.A., Chawla, N. and Toledo Filho, R.D. 2008. Tensile behavior of high performance natural (sisal) fibers. Comp. Sci. Technol., 68(15): 3438-3443.

Sabarish, K.V., Dhanasekar, K., Manikandan, R., Ancil, R., Venkat Raman, R. and Selva Surender, P. 2017. Strength and durability evaluation of sisal fiber reinforced concrete. Int. J. Civ. Eng., 8(9): 741-748.

Sangeetha, S.P. and Joanna. P.S. 2014. Flexural behavior of reinforced concrete beams with partial replacement of GGBS. Am. J. Eng. Res., 03(01): 119-127.

Wei, J. and Meyer, C. 2014. Improving degradation resistance of sisal fiber in concrete through fiber surface treatment. Appl. Surf. Sci., 289: 511-523.