

Coir Fiber Reinforced Concrete

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Rec date: Jul 04, 2014; Acc date: Jul 31, 2014; Pub date: Aug 10, 2014

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Abstract

Green approach refers to a use of natural and renewable source of energy replacing or reducing environmentally unfriendly materials like steel. The present study discusses about the importance of coconut fiber as an ad-mixture for roofing, its advantages and scope in future. As we all know, steel is used as a reinforcing material for holding the concrete and making it crack resistant. But, due to its number of demerits, which includes its high cost, non-recyclability, corrosiveness, high weight and low strength ratio, with time, a number of innovations have taken place. "Textile Composites" entertains the use of coconut fiber, which can also be used as a strengthening material for roofing apart from steel.

Two inherently different materials out of which one belongs to textiles are mixed to form a new material, different to both but better in properties are called as textile composites.

Use of coconut fiber (Coir) should be valued over Steel for the following reasons like low cost, recyclability, non-corrosiveness, low thermal conductivity (natural cooling), high strength and low weight ratio. In earthquake prone areas where frequent damage to infrastructure takes place, the use of Natural fibers such as Coir instead of steel will prove advantageous. In this paper, we will be focusing on the above-mentioned points in detail and our research work will prove that use of coconut fiber in roofing proved to be very lucrative.

Keywords: Coconut (COIR) fiber; Reinforcement; Crack resistant; Textile composites; Steel; Roofing; Strength; Cost; Thermal conductivity

Introduction

India, endowed with an abundant availability of natural fiber like coconut fiber, has focused on the development of green composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as substitutes in housing & construction sector. The development of natural fiber composites in India is based on a two-pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers (Figure 1).

The fiber extracted from the husk of a coconut fruit commonly known as coir fiber, has been traditionally used in tropical regions of Asia, Africa and South America.

The husk consists of Coir fiber and a corky tissue called pith. The husk is immersed in water for 6 - 9 months. This process is called retting. Retting removes some of the dirt and natural enzymes present in the fiber giving it a golden color. The fiber is then extracted by beating it manually using a mallet or by a mechanical extractor machine. This leaves the outer skin of the coconut fruit along with the corky pith. Pith finds large-scale use in horticulture as a growing medium. The fiber thus extracted is used to make an ever-increasing range of products, which can be used in building and infrastructure as well [1-5].

Material and Methods

Composites are artificially produced multiphase materials having a desirable combination of the best properties of the constituent phases or more precisely these are the materials consist of fibers of high strength and modulus embedded in a matrix with distinct interfaces between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. Fibers are the principal load-carrying members, while the surrounding matrix keeps them in a desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperature and humidity. Thus even though the fibers provide reinforcement to matrix, the later also serves a number of useful functions in fiber-reinforced composites (Figure 2).

Two inherently different materials are mixed to form a new material called composite material, which is different to both but better in properties. The two constituents of the composites are called matrix and resin. Matrix it is the main constituent of composites materials mainly responsible for its mechanical properties. Adhesive/Resin normally it is a synthetic polymer with an objective to bind the matrix elements [6,7]. Composites materials are preferred over contemporary metallic materials due to their higher strength- to-weight ratio, light weight, long life, low cost, design flexibility [1,6].

Constituents of Composites

Matrix (Resin)

The matrix is to transfer load to the fiber network & maintaining the fiber orientation. The matrix also protects from damaging environmental conditions such as humidity and high temperature. The resin often dictates the process and processing conditions. The matrix must also meet certain requirements in order to first be suitable for FRP process and ensure a successful reinforcement of it. The matrix must be able to properly saturate and bond with fibers within a suitable curing period. The matrix should preferably bond chemically with the fiber reinforcement for maximum adhesion. The matrix must also completely envelope the fibers to protect them from cuts and notches that would reduce their strength and to transfer forces to the fiber. The fiber must also be kept separate from each other so that if failure occurs it is localized as much as possible, and if failure occurs, the matrix must be deboned from the fiber for similar reason. Finally, the matrix should be of a plastic that remains chemically and physically stable during and after molding process. To be suitable for reinforcement material fiber additive must be increase the tensile strength and modulus of elasticity of matrix and meet following conditions, fibers must exceeds critical fiber content is the strength and rigidity of fiber itself must exceed the strength and rigidity of the matrix alone and therefore must be optimum bonding between fiber and matrix. The various matrices used for manufacturing of composite such as plastic, metal, ceramic or rubber. Here, the Matrix is Concrete (Figure 3) [5,6,8].

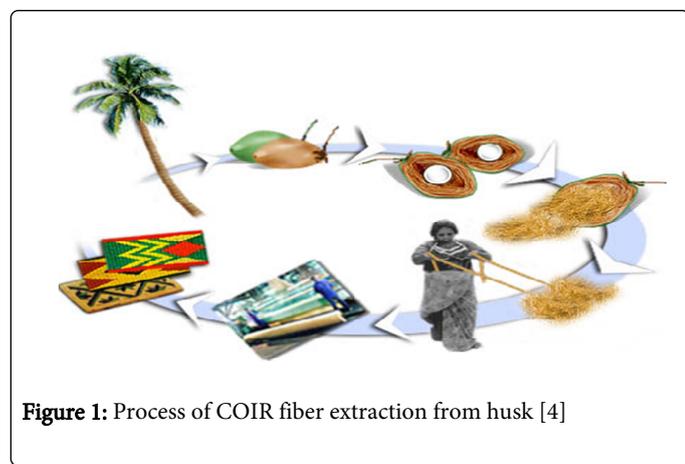


Figure 1: Process of COIR fiber extraction from husk [4]

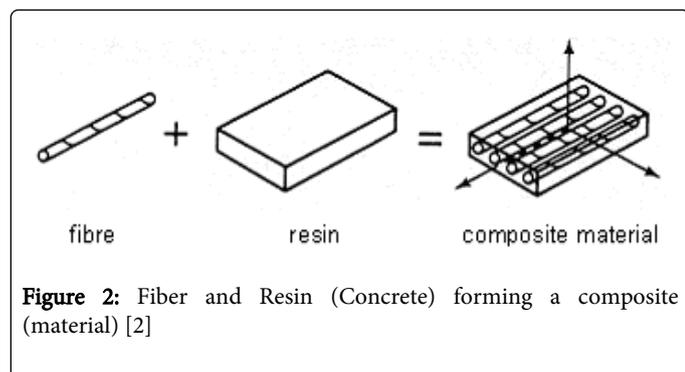


Figure 2: Fiber and Resin (Concrete) forming a composite material [2]

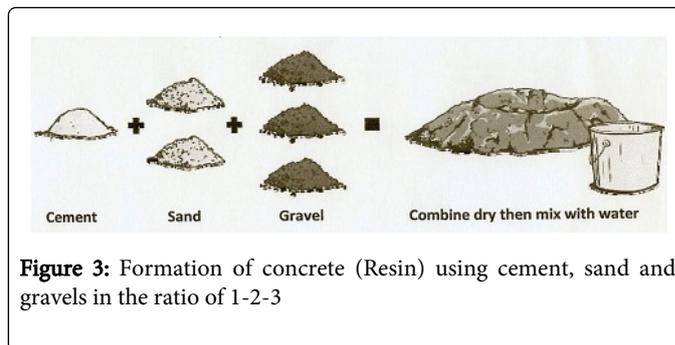


Figure 3: Formation of concrete (Resin) using cement, sand and gravels in the ratio of 1-2-3

Reinforcement

Reinforcement is the substances, which gives strength to the composite. Reinforcement is used with resin system to improve the mechanical properties of cured resin and to provide a usable product. The mechanical strength of reinforced plastic component is largely dependent on the amount, arrangement, and types of reinforcing fibers in the resin matrix. Typically, higher the fiber content, greater the strength. The arrangement has to do with the way that fibers are positioned. Here, the reinforcing material is Coir fiber [9,10].

Fiber Reinforcement Concrete (FRC)

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is approximately just one tenth of its compressive strength. As a result for these characteristics, concrete flexural members could not support such loads that usually take place during their service life. Historically, concrete member reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength.

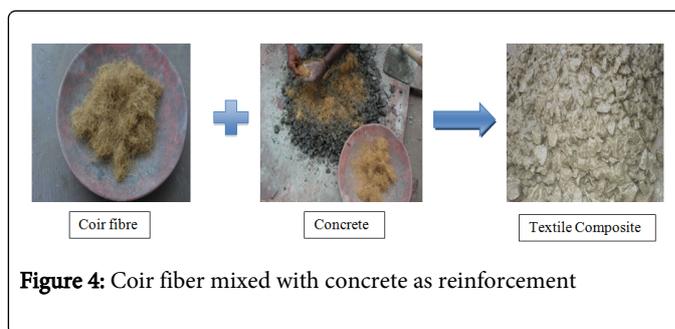


Figure 4: Coir fiber mixed with concrete as reinforcement

Furthermore, steel reinforcement is adopted to overcome high potentially tensile stresses and shear stresses at critical location in concrete member. Even though the addition of steel reinforcement significantly increases the strength of concrete, the development of micro cracks must be controlled to produce concrete with homogenous tensile properties. The introduction of fibers is brought in as a solution to develop concrete with enhanced flexural and tensile strength, which is a new form of binder that could combine Portland cement in bonding with cement matrices. Fibers are most generally discontinuous, randomly distributed throughout the cement matrices (Figures 4 and 5) [11-14].

Change in trends in use of fibers as reinforcement dates back from ancient Egyptian times which used Hoarse Fiber (BC) for reinforcement. Later came Asbestos (1900) but Asbestos had Health

Hazards so Fibers like Steel, Glass, Carbon started in late 1960 were used and today its Natural Fibers- Coconut Coir (Figure 6).

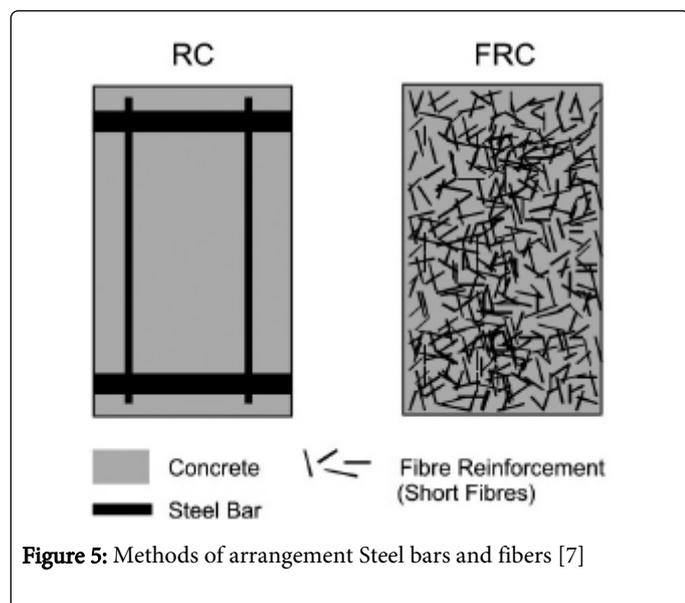


Figure 5: Methods of arrangement Steel bars and fibers [7]

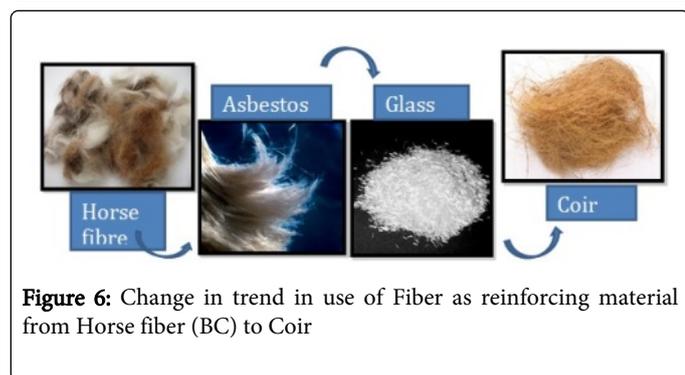


Figure 6: Change in trend in use of Fiber as reinforcing material from Horse fiber (BC) to Coir

Plan of action

After doing a deep research on our topic we decided to conduct it practically. For this, we conducted a number of experiments with various hit and trial methods and were able to reach to a final conclusion.

Our plan of action was as follows:

- Firstly, we prepared 6/6 inches 3 cubes of concrete which consisted of the cement, sand and gravels. Main objective of preparing the concrete cubes was that we wanted to compare coconut fiber reinforced concrete cubes with the normal concrete cubes.
- Then we again prepared 6/6 inches 3 cubes, in which coconut fiber was reinforced with concrete in 1%.
- Lastly, we prepared 6/6 inches 3 cubes, in which coconut fiber was reinforced with concrete in 0.25%.
- Not only this, we also prepared small blocks of cement and coconut fiber which displayed amazing results for hut making.
- Various other tests were also conducted which made our research work more evidence proof.
- Tests are as follows - CRUSHING STRENGTH, CRUSHING LOAD, COST ANALYSIS, DENSITY, CORROSIVE NATURE and THERMAL CONDUCTIVITY.

Results and Discussions [15-18]

Crushing load

First test conducted by us was the crushing load test. For the above test we prepared 6/6 inches 9 cubes (Figure 7).

- 3 cubes for plain concrete.
- 3 cubes with 1% coconut fiber reinforced with concrete.
- 3 cubes with 0.25% coconut fiber reinforced with concrete.

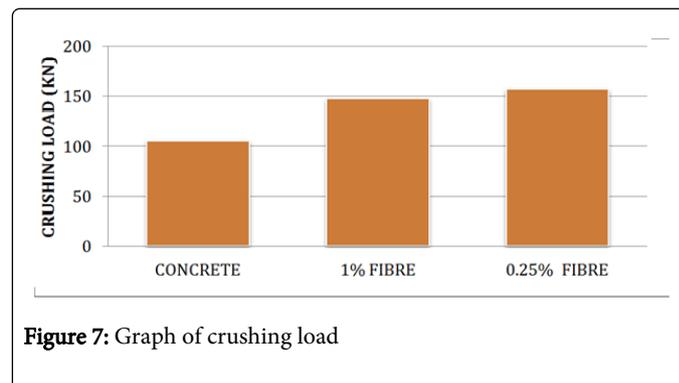


Figure 7: Graph of crushing load

From the above graph it is clear that when 0.25% coconut fiber is reinforced with concrete it shows the best CRUSHING LOAD (i.e. 158 KN) as compared to 1% coconut fiber reinforced with concrete and 100% concrete.

We also prepared coconut coir reinforcement concrete board and bogs and tested them for compression strength and analyzed its cost effectiveness, weight to strength ration etc. whose results have been mentioned (Table 1).

Sr. No.	Cube specifications	Grade of Concrete	CRUSHING LOAD (KN)	
1	CONCRETE	M-15	116	5.16
2	CONCRETE	M-15	110	4.89
3	CONCRETE	M-15	92	4.09
4	1% FIBER	M-15	152	6.76
5	1% FIBER	M-15	148	6.58
6	1% FIBER	M-15	144	6.4
7	0.25% FIBER	M-15	154	6.84
8	0.25% FIBER	M-15	152	6.76
9	0.25% FIBER	M-15	168	7.47

Table 1: Represents the detailed report of strength tests carried out on the concrete cubes on Universal strength testing machine

Cost analysis

As compared to Steel, the rate of coir is as low as 0.5 \$/ kg. It is obvious that if coir is successful in replacing the use of steel even by a small proportion, it is definitely going to be very cost effective and profitable as shown in Figure 8.

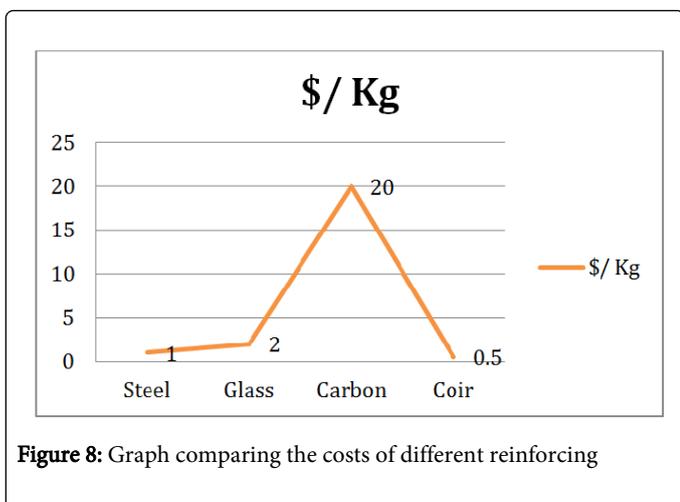


Figure 8: Graph comparing the costs of different reinforcing

Thermal Conductivity

Coir has very low thermal conductivity of 0.12 kcal /m²hr/°C which serves as natural cooling. We conducted a test at our institute for testing the thermal conductivity of coir fiber reinforced concrete. We prepared two small cement and brick sheds of 3X3 Sq. Feet. One shed had normal concrete roof and the other had concrete roof with coir in it. We observed and noted the temperature in the thermometer every hour inside both the sheds as shown in Table 2.

	Normal Room Temperature	Temperature Inside Coir Web Concrete roof ° C
10.00 AM	34.67	24.83
11.00 AM	37.67	28.25
12.00 PM	39.67	30
1.00 PM	41.5	32
2.00 PM	41.42	31.75
3.00 PM	41.25	32
4.00 PM	39.17	31.33
5.00 PM	37	30.67
6.00 PM	34.5	28.5

Table 2: comparing the temperatures inside normal roof and inside Coir Reinforced roof

Other advantages

Over half of the population around the world is living in slums and villages. The earthquake damages in rural areas get multiplied mainly due to the widely adopted non – engineered constructions. On the other hand, in many smaller towns and villages in southern part of India, materials such as nylon, plastic, tyre, coir, sugarcane biogases and rice husk are available as waste. So, here an attempt has been made to investigate the possibility of reusing these locally available rural waste fibrous materials as concrete composites [19].

Future scope of our project

In our upcoming research work on Coir fiber we will be focusing on reducing the steel diameter used as a reinforcing material with concrete by wrapping the steel rods with COIR fiber, this will not only prevent the steel rods from being corroded but also improve the strength as well as thermal conductivity of the room. As the steel diameter is reduced, the steel consumption is decreased. Also, we believe, soon, every small thing is to be replaced by a textile material. Talking about infrastructure, we can use coconut fiber ropes in conjunction with steel, we can replace wooden furniture by a compressed coconut fiber board reducing the use of wood. We can also use Textile fabrics in beams of infrastructure for better support and reinforcement. Even in cement flooring, coconut fiber can be used as an admixture improving its strength. Thus, we have planned to form a room filled with textiles as an innovative infrastructure creation which is predicted to be the future of Civil Engineering.

Conclusion

India, endowed with an abundant availability of coir fiber has focused on development of natural composites. Their development is based on a two-pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers. Government and related organizations should take proper steps in enhancing the research and using Coir as reinforcing material in construction.

From our research work, we could conclude the following:

- Steel is used as a reinforcing material for holding the concrete and making it crack resistant. But, due to its number of demerits, which includes its high cost, non-recyclability, corrosiveness, high weight and low strength ratio, with time a number of innovations have taken place. “Textile Composites” entertains the use of coconut fiber, which can also be used as a strengthening material for roofing apart from steel. Our study and experimental work says coir fiber has got a great potential to be used in place of steel for reinforcement or at least be used as a blend with the former for the advantages like better strength, low cost, natural cooling etc.
- With increasing infrastructural demands, a substitute from natural origin was truly needed and I feel my research has filled this breach. The near future will surely use natural fibers like coir, jute or banana for reinforcement and research in these fields should be given a growing concern.
- Use of Coir fiber gives natural cooling effect due to its near to zero thermal conductivity.
- Cost wise, natural fibers like coir is very cheap in places like India and could be potentially used in construction work
- It is obvious that coir will not have any risk of getting corroded like steel so that is an added advantage.

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