Mehran University Research Journal of Engineering and Technology

https://doi.org/10.22581/muet1982.3042

2024, 43(4) 82-90

Effects of coconut fibers on flexural and tensile strengths of concrete maintaining uniform workability

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Received: 01 October 2023, Accepted: 08 September 2024, Published: 01 October 2024

K E Y W O R D S

Flexural Strength

Coconut Fibers

Super Plasticizers

Constant Workability

Tensile Strength

A B S T R A C T

Concrete, the most commonly utilized building material, possesses a high compressive strength but has very low tensile and flexural strength. Steel is the most popular type of flexural and tensile strength enhancer in Cement concrete, however due to the rapid increase in the cost of steel as a result of the financial crises experienced in several countries, research is currently being done to use other affordable and easily accessible material to decrease the quantity of reinforcement steel, as Tensile as well as flexural reinforcement. Coconut fiber, also known as coir fiber, Due to its thread-like structure has previously been shown to help boost concrete's flexural and tensile strength, having said that it negatively affects the workability of fresh concrete. So we can use a workability enhancer to overcome this negative effect while getting optimum benefits in terms of enhancement of flexural and tensile strength. The goal of the study is to discover how coir fiber affects concrete's flexural and tensile strength under uniform workability, with the help of a super plasticizer. It also attempts to find the ideal content of fiber to be used in concrete. The methodology is that with the assistance of a hit-and-trail procedure, we find out the amount of plasticizer needed for each fraction of fiber percentage, to create a constant range workability of 40±5mm for every proportion. Beams and cylinders were cast, curing was done for 28 days, and then their flexural capacity and tensile strength were analysed for each fraction of coconut fiber: 0%,0.4%,0.8%,and1% (by WT of cement)in comparison to plain concrete, the flexural strength improved by 21 percent,25 percent,and15.24 percent at fibers proportions of 0.4%, 0.8%, and 1%, respective, while the tensile strength increased by 29.66 percent, 38.66 percent, and 22.81percent. The best outcomes were discovered at 0.8%. It's determined that the addition of coir fiber results in a considerable improvement in flexural strength and Tensile strength meanwhile plasticizer proves to be good cure against workability loss due to fibers.

1. Introduction

Concrete , most used building material, having some key characteristics like mechanical capabilities durability, and aesthetics, it has completely superseded all other materials. There are two main areas of research increasing mechanical strength, and durability. Engineers have a lot of emphasis on the sustainability of structures, therefore the structure should be secure, affordable, and environmentally friendly to meet the objectives of sustainable building[1]. For the recent past, the utilization of fibers in plain concrete has intensified because fiber seems to be beneficial for the improvement of mechanical strengths of concrete, 20% to 25% significantly in Tensile and Flexural Strength [2]. However, following the COVID-19 scenario, developing nations

throughout the world, experienced an unprecedented rise in price as well as an increase in the cost of construction materials. Steel and cement prices have surpassed all previous records. This market inflation has a direct impact on construction sector. etc. Researchers need to find alternatives for these pricey building materials so they can partially replace them, especially steel, Utilization of waste and inexpensive materials that can improve the flexural and tensile strength is one of the best techniques that allow a reduction in the amount of steel necessary for flexural reinforcement as some proportion of that provided through these materials and fibers are one of them. On the other hand, by reusing these waste products, such as Natural Fiber in the construction sector, the objectives of waste management can also be accomplished. Because of the strength of plain concrete will be enhanced by fiber, less steel will be utilized as flexural reinforcement in concrete, Due to its observable beneficial effect on mechanical strength, coir fiber, usually referred to as coconut fiber, is the most commonly used natural fiber in concrete. According to earlier studies, coconut fiber significantly increased the flexural and tensile strengths of concrete[3]. In the past, coir fiber was employed practically in the construction industry in a variety of ways. In plaster mixtures, coir fiber is employed [4]. As a cheap roofing material has been used before, roofing tiles have been made using coir fiber [5].

Wall paneling has been made using coir fiber[6]. According to Khan, Rehman, and Ali [7], coconut fibers had utilized for lowering thickness in inflexible pavement. In addition to all these beneficial effects, using fiber in concrete has one peculiar effect that adversely affects the workability characteristics of fresh concrete as workability is seriously affected by fiber inclusion in concrete. Workability is one of the most crucial characteristics of green Concrete, Researchers and the Construction Industry will be getting positive effects from the flexural enhancement of ordinary concrete through coconut fibers while maintaining a constant workability concrete by super plasticizer to address and resolve the difficulty of coconut fiber's workability limitations. Waste management is also possible because coir fiber, a waste product that is appropriately managed through use in concrete, the goal of the study is to ascertain the impact of coconut fibers on the tensile and Flexural strength under Constant workability with the aid of super plasticizer.

Fig. 1. Processed Coconut Fiber

Table 1

Previous investigation on coir fiber reinforced concrete

No	Reference	Title	Outcomes
1	(Hartwell 2011)[8]	Coconut fiber reinforced Concrete	Flexural strength increases as coconut fiber content rises, with an increase in strength peaking at 5% of coir fiber by weight of cement.
2	(Rubin and Baskar 2014)[9]	e use of coir fiber in different lengths as well as different proportions examining effect on 28 days compressive strength and tensile strength of concrete	maximum compressive and tensile strength found when 25 mm (about 0.98 in) fiber used.
3	(Nadgouda 2014)[10]	Coconut Fiber Reinforced Concrete	Flexural performance at 3% coir fiber after 28 days was 12% better than with standard concrete.

4	(Sarange and Sinhe 2016/)[11]	Mechanical capabilities of hybrid fiber reinforced concrete	The flexural behavior was significantly enhanced, and the best results came from using 0.75%PP fiber and 0.25%CF.
5	(Chandel et al. 2016)[12]	Study of (CFRC) Over (PCC)	The compressive strength rose by 13% at the 1% of fiber concentration that produced the best results. split tensile strength increased by 40%, and flexural strength increased by 15%.
6	(Nasir, Ayoub, Zafar, Bilal, Hazoor, and Kakar 2017)[13]	Concrete Reinforced with Natural Waste Fiber (Coir and Jute) Strength Properties Experimental Study	There was an increase in flexural strength. The best results were from concrete at a fiber quantity of 1.5 percent by volume.
7	(C achudan et al. 2018)[14]	Experimental Investigation of Concrete with Coir Fibre	Positive results were found at 3 percent coconut fibers by weight of cement.
8	(Seker and Kandasemy 2018)[2]	The mechanical and bond characteristics of coir fiber in coconut shell concrete	Flexural strength was reported to improve in coconut shell and regular concrete, with optimum increases of 30.63% and 50.63%, respectively.
9	(Khan and Ali 2018)[15]	Concrete created with coconut fiber that has been medium-strengthened and how super plasticizer affects its qualities	The quality results were obtained with moderate strength CFRC that had optimal silica fumes (15 percent), coir fiber (2 percent), and superplasticizer (1%) contents.
10	(Babafemi, Kolawole and Olalusi, 2019)	Determination of the mechanical strength and Concrete durability reinforced with coir fibres.	Workability was decreasing with an rise in fiber proportion W/C ratio raised to 0.55 making the mix comparatively workable compressive strength was raised by twenty-two % Split tensile strength was raised by fourteen % best results found at 0.5%
11	(Ramesh Kumar and Kesavan, 2020)[16]	Structural properties determination coconut fiber ash mixed concrete in M-20 grade mix. Coconut fiber as well as coconut fiber ash	Coconut fiber and coconut fiber ash were used at the optimum percentage of 5 and 15, respectively. compression tensile bending stress was found to be maximum at that
12	(Khan, Ali and Rehman 2020)[7]	effect of silica-fume content in unreinforced concrete and concrete with coir fibers for roads	When 10% silica is used, plain concrete performs better, and coconut fiber concrete performs better when 15% silica

			is used, reducing the depth of the CC road by 4 percent and 8 percent, respectively.
13	(K.R et al. 2021)[17]	Mechanical Characteristics of Concrete Using Fiber and Coconut Shell as Additives	1% of coconut fiber in concrete was discovered as perfect amount for maximum flexural and tensile strength.

Per past research, fibers from coconut previously utilized within the concrete are from 0.4% to 5% weight-based or Volume-based of cement. The ideal coconut fiber % ranged from 0.1% to 2% by weight of cement in several studies. Therefore, in this study, we employed coir fiber in various proportions, ranging from 0% to 1% by weight of cement.

2. Methodology

2.1 Materials

The quality and strength of the many components that make up concrete determine the concrete's strength.

i) Fine aggregates

It is a crucial component of concrete. It occupies the space between the coarser aggregate and aids in creating a workable and consistent mix.

Table 2

Fine aggregate test results

Tests on Fine Aggregate	
Gradation of coarse aggregate	Fineness Modulus:3.14
WA (water absorption)	1.41%
SG	2.631
Unit weight (loose)	$1480\frac{kg}{m^3}$
unit weight (compacted)	$1601\frac{kg}{m^3}$

ii) Coarser aggregate

About 65% to 70% of the volume of concrete is made up of coarse aggregate, making it one of the most crucial components. 20 mm is the maximum size of the coarse aggregate.

Table 3

Coarse aggregate testing results

Tests on coarse aggregate	
coarse aggregate gradation	< 20mm
WA	1.19%
SG	2.57
Unit weight (loose)	$1276\frac{\mathrm{kg}}{\mathrm{m}^3}$
Unit weight (Compacted)	$1410\ \frac{\mathrm{kg}}{\mathrm{m}^3}$

iii) Cement

The most significant component of concrete is cement, which also serves as the material's primary binder. The findings of tests conducted.

Table 4

Cement test results

Results	
Cement Fineness	95%
Cement (Normal Consistency)	0.33
IST	28 mints
FST	8 hours 53 minutes

iv) Water

Water quality is also an important aspect while checking suitability of water for concrete work.

Table 5

Testing on water

Testing results on water	
Hardness	259mg/L
Chloride content in water	171mg/L
TDS	770mg/L
PH	7.77
Acidity	0mg/L
Alkalinity	0 mg/L

v) Coconut fiber

Coconut fiber helps to improvise the mechanical strength and durability of plain concrete [9], following are the properties of coir Fiber

Table 6

Coir fiber properties

Fiber Properties	
Coir fiber Length	50mm
Coir fiber dia	0.4mm-0.8mm
Specific gravity	1.18
Density	1.4-1.5g/cc

vi) Expanplast SP511 [18](complies with ASTM C-494)(Fospak n.d.) (ASTM C 494/C 494M - 04 2013)

It is a water-reducing superplasticizer used to prevent concrete's loss of workability as a result of coir fiber and to keep workability constant.

3. Experiment Design and Procedure

Coarse aggregate, cement, Fine aggregate, water, superplasticizer, and processed coir fiber were all gathered.

The DOE Mix method was used to conduct the M20 grade concrete with a 20MPA strength mix design for normal concrete. A mix design 1:2.05:3.07 was achieved with a W/C of 1/2. [16]

The chosen fiber proportions were 0 percent, 0.4 percent, 0.8 percent, and 1 percent by weight of cement. [11]

Trial mixes were created at each fiber percentage, and plasticizer was added in various amounts (in ml/kg of cement) to provide uniform workability of concrete mixes slump(ASTM C143)[19] ranges of 40 ± 5mm. The slump test trail for constant workability repeated until the range of 40 ± 5 mm for a specific fiber content was reached. The procedure was repeated for each fiber percentage that was chosen, and Table 6 shows the outcomes of successful trials for each proportion.

After being cured for 28 days in clean water as per previous research and wanting to see ultimate strength , the beams(size and cylinders underwent center point loading tests to determine their flexural strength and split tensile tests on the cured beams and cylinders, respectively.28 day curing period was in accordance with previous research [10] [20].

Beams of 50 cm x 10 cm x 10 cm, cylinders 10 cm x 20cm Dimension were both cast. A total of 12 beams (3 samples per proportion and 12 Cylinders were cast. The slump test was again conducted prior to casting of beams and cylinders to confirm the outcomes of the constant workability trials.

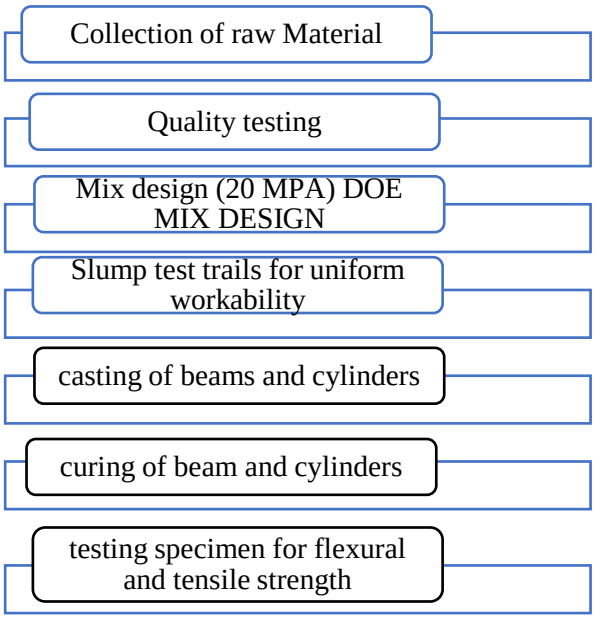

Fig. 2. Flow Chart of The Methodology

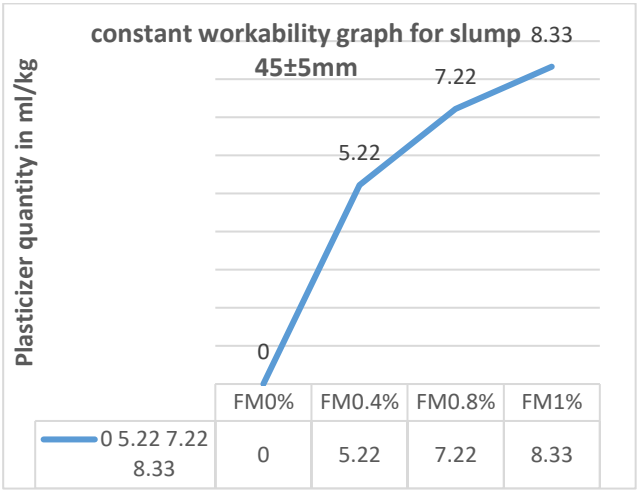

Fig. 3. Graph of Plasticizer Quantity vs. Fiber Content

The results showed that the plasticizer requirement increase with increasing fiber content as workability was reducing.

Table 7

Mix proportion

Mix no	Water	Cement	Coarse aggregate	Fine aggregate	Fiber proportions	Super plasticizer quantity at 45mm±5mm Slump) (ml/kg of cement)
FM00%	186 kg/m^3	372 kg/m^3	767 kg/m^3	1142 kg/m^3	0 kg/m^3	0
FM0.4%	186 kg/m^3	372 kg/m^3	767 kg/m^3	1142 kg/m^3	1.488 kg/m^3	5.22
FM0.8%	186 kg/m^3	372 kg/m^3	767 kg/m^3	1142 kg/m^3	2.976 kg/m^3	7.22
FM1%	186 kg/m^3	372 kg/m^3	767 kg/m^3	1142 kg/m^3	3.72 kg/m^3	8.83

FM=Fiber Reinforced Concrete Mix

4. Results and Discussions

4.1 Flexural Strength Analysis

Flexural Strength was tested on beams in the Universal Testing Machine, and failure cracks were observed.

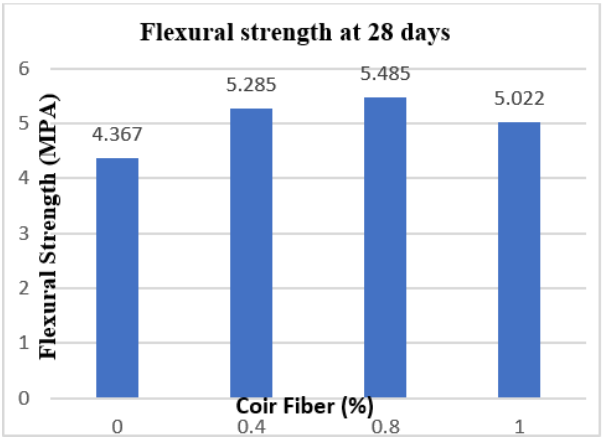

Fig. 4. Flexural Strength Graph

Flexural strength was calculated for each proportion of fiber in each of the three samples by testing according to ASTM C293[21].

Fig. 5. Failure Cracks in Coir Fiber Reinforced Beam

Table 8

Flexural strength determination and results

S.no	Fiber content (%)	Sample no:	Failure load (N)	Flexural strength (MPA)	Average strength	Increase in strength (%)
		1	5935	4.451		
1	FM0	2	5320	3.99	4.367	-
		3	6218	4.663		
		1	6930	5.1975		
2	FM0.4	2	7530	5.6475	5.285	21
		3	6680	5.01		
		1	7830	5.872		
3	FM0.8	2	7170	5.377	5.458	25
		3	6833	5.125		
		1	6794	5.0961		
4	FM1	2	6301	4.7273	5.022	14
		3	6990	5.2421		

It is observed that flexural strength raised with increment at each fiber proportion, with 0.8% of fiber by weight of concrete producing the best results. As previously observed from recent research on coir fiber reinforced concrete[22] the coconut fibers intensify the flexural strength of concrete. The primary factor causing this improvement is the adding of coir fiber in concrete, which prosper the ductility of the material and improves coir fiber resistance to flexural stress development in concrete. Coir fiber also initially increases the bonding between aggregate, which has shown an increase up to 0.8% while after exceeding a limit, it acts as a detriment rather than an improvement and functions as an additional load on plain concrete, which is why the flexural strength has decreased at 1%. According to previous studies, coir-reinforced beams have superior bonding qualities since only minor cracks show up rather than collapsing under failure loads[17]. Due to the fact that coir fiber has 5–6 times greater strain development than other natural fiber, it can improve concrete's ductility [23].

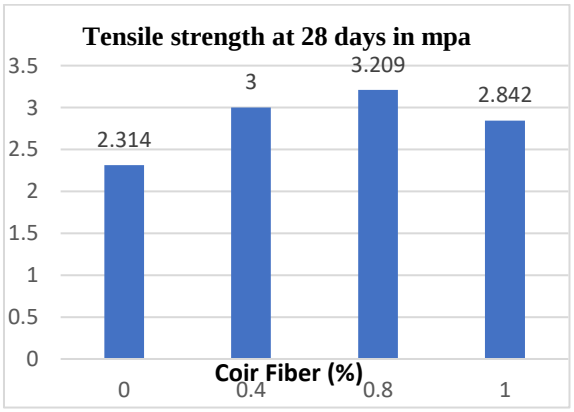

Fig. 6. Tensile Strength Graph

4.2 Analysis of Split Tensile Strength

Tensile strength measurements were made for all three Samples for each fraction of fiber after failure cracks were observed during the tensile strength tests on

cylinders in the UTM. All relevant testing methods were adhered to, and testing was conducted in accordance with ASTM C496 [24]and standard operating procedures.

Table 9

Tensile Strength determination and results

S.no	Fiber content (%)	Sample no:	Failure load (N)	Tensile strength (MPA)	Average strength	Increase in strength (%)
		1	74380	2.367		
1	FM0	2	71320	2.272	2.314	-
		3	72345	2.302		
		1	95388	3.038		
2	FM0.4	2	97843	3.090	3.00	29.66
		3	93442	2.991		
		1	101660	3.269		
3	FM0.8	2	98450	3.192	3.209	38.66
		3	102750	3.2961		
		1	87250	2.777		
4	FM1	2	91750	2.920	2.842	14
		3	89050	2.835		

FM= Coir Reinforced Fiber Concrete

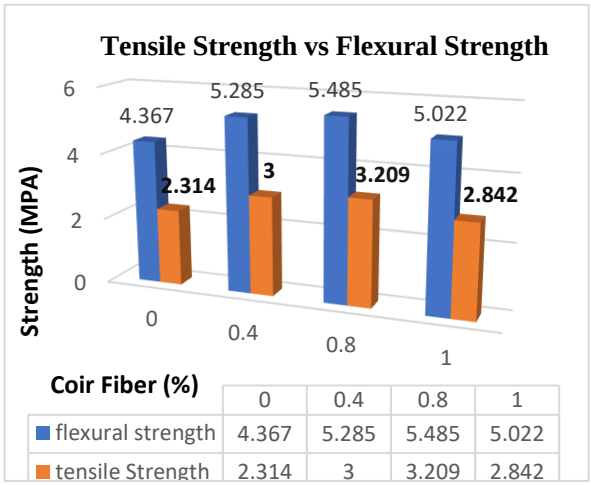

Fig. 7. Failure of Cylinder Under UTM

Fig. 8. Comparative Graph of Flexural and Tensile Strength

The results demonstrated that tensile strength increased as fiber content increased, with 0.8% fiber producing the best results.

The literature on CRFC [12]also shows that the coconut fibers have increased tensile strength. The fundamental reason for this increase is that adding coir fiber to concrete increases its ductility, which in turn increases its resistance to developing tensile stress. Coir reinforced concrete cylinders had also presented better cohesive characteristics as shown Only minor crack appeared on cylinder comparative of total collapsed cylinders in case of plain concrete.

Concrete in the start coir fiber increase the bonding between aggregate which has shown the increase in start up to 0.8% while after exceeding a limit, instead of acting as enhancement its acts as an addition load on plain concrete that's why we have seen a decrease in flexural and Tensile strength at 1%. Coir fiber itself has five to six times more development of strains so it's gives the same enhancement to concrete by increasing ductility (S.B 2015).

From the result it is shown that coir fiber reinforcement help in increasing tensile and flexural strength by significant proportion comparative effect on both mechanical properties are shown below in graph.

Graph shows that the flexural strength of plain and coir reinforced concrete is more than that of tensile strength however impact of fiber on tensile strength is more than on flexural as optimum increase in about 39% in tensile strength of concrete than in flexural strength which is 25% when compared with ordinary concrete.

4.3 Workability Analysis

Workability seemed to be decreasing with increasing fiber content validating the previous study done on coir fiber several trials done each proportion (plasticizer was used 0-10 ml/kg) and founded that the workability was increasing with increase of plasticizer

a fixed proportion was found against each fraction of fiber to get slump/workability in desired range.

5. Conclusion

a) Flexural resistance (Strength) improved by 21 percent on fiber proportions of 0.4%, 25 percent on 0.8%, and 14 percent at 1% proportion, and the 0.8% fiber percentage produced the best results.
b) The tensile strength of plain concrete increased by 29.66% at fiber proportions of 0.4%, 38.66% at 0.8%, and 22.81% at 1%; the 0.8% fiber proportion produced the best results.
c) The properties of green coir reinforced concrete were found to be enhanced by the addition of super Plasticizer and the utilization of plasticizer help during placing, mixing, and casting etc. Successful trails for plasticizer quantity constant workability of 45±5mm for fiber proportion FM0,FM0.4,FM0.8,FM1 were 0ml/kg,5.22ml/kg,7.22ml/kg,8.33ml/kg respectively.

6. Future Recommendation

For future consideration a trail based research in term of mechanical strength of concrete can be done, it can be found that requirement of flexural And tensile steel can be reduced by which percentage when concrete is already reinforced with optimum coir fiber content e.g. plain concrete reinforced with 100% design steel amount, coir reinforced concrete with 95% design steel amount inter comparison of results.

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