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STUDY THE EFFECT OF COIR FIBER ON COMPRESSIVE STRENGTH OF CONCRETE

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Abstract
The new generation of fiber reinforced concrete is strong, tough, and durable. It finds application in several construction areas such as slabs on grade, shotcrete, architectural panels, precast goods, offshore buildings, seismic structures, thin and thick repairs, crash barriers, footings, hydraulic structures, and more. Researchers have suggested steel, glass, natural fiber polypropylene, carbon, polyester, acrylic, and aramid. Concrete needs reinforcement to improve engineering properties. The study compares coconut Fiber reinforced concrete to conventional concrete based on lab experiments. A concrete mix meets IS 456-2000's minimum M20 grade. This experiment examines the compressive strength of concrete with coir Fibers at 0.43, 0.45, and 0.5 water cement ratios. For compressive strength, coir Fiber reinforced concrete uses 1%, 1.5%, and 2% fibers by weight of cement. Experimental results show that coir Fiber reinforced concrete's compressive strength increases maximum at 2% coir Fiber by weight of cement for w/c ratios of 0.43, 0.45, and 0.5. The results show that compressive strength increases by 9.9% for w/c ratio 0.43, 5.81% for 0.45, and 4.38% for 0.50.

Keywords: Coir Fiber, Compressive strength, Durability, Fiber reinforced concrete, Compressive strength.

Introduction
The chemical reaction between cement and water results in the formation of concrete, a solid substance resembling stone. Concrete is composed of hydraulic cement, water, coarse aggregate, and fine aggregate. However, concrete is brittle and weak in tension, cracking and failing under small loads. Concrete failure occurs as cracks, including drying shrinkage microcracks, expand over time. There are many ways to strengthen concrete's tensile strength. Steel reinforcement has been used to increase strength and resist tensile and shear stresses, but micro crack control is still important. New Portland cement-fiber-reinforced concrete improves flexural and tensile strength. This chapter covers the development, applications, benefits, and drawbacks of fiber-reinforced concrete to improve concrete performance. Fiber reinforced concrete development, applications, benefits, and drawbacks are covered in this chapter.

Figure 1: Coconut Tree, Coconut and Coconut Fibers

Banthia, N., & Yan, C. [4] investigated composites and observed that crushed rubberized concrete and damping ratio ground achieved 144% and 75% of PC performance, respectively. Bilba et al. [5] examined cement composites reinforced with sugarcane bagasse fibers. Romildo D. Toledo Filho et al. [15] created long-lasting composites of vegetable fiber and mortar. Ramakrishna and Sandararajan

[13] experimented to assess the ability of cement sand mortar (1:3) slabs to withstand impact loads. The fibres were incorporated at four distinct proportions (0.5%, 1.0%, 1.5%, and 2.5% of the cement's weight) and three varying lengths (20 mm, 30 mm, and 40 mm).The coconut fibers, which had 2% fibre and 40mm length had the highest impact energy absorption, 253.5J. At the point of final failure, all fibers experienced fracture except for the coir, which exhibited fiber pull-out failure. In a study by Reis [14] the researcher investigated the mechanical characteristics the epoxy polymer concrete specimens were reinforced with coconut, sugarcane bagasse, and banana fiber. Coir fiber reinforced polymer concrete exhibited superior fracture toughness and fracture energy compared to other reinforced polymers, with a 25% increase in flexural strength. Baruahand Talukdar [12] conducted experiments on plain concrete and FRC using fiber volume fractions ranging from 0.5% to 2.The fibers utilized were steel, synthetic, and natural fibers (namely jute and coir). Gunasekaran and Kumar (2008) conducted an experiment where concrete supplemented with coir fiber demonstrated a water absorption rate that was 24% higher than that of ordinary Portland cement. The compressive strength of the concrete rose by 19.1% compared to the plain concrete after 28 days of curing the cube. Yalley et al. [16] in the United Kingdom, the researchers examined the impact of coir fiber on the characteristics of concrete. Their study centered on the analysis of Ghanaian coir fiber. They conducted tests to evaluate the compressive, tensile, torsional, toughness, and resistance to cracking and spalling. Noor Md. Sadiqul Hasan et al. [11] conducted a study in Malaysia to investigate the physical and mechanical characteristics of concrete when coir fibers were added based on volume. Their test involved a microstructural examination of coir fiber bonding using a scanning electron microscope. Domke P. V. [7] examined the effects of coir fibres and rice husk ash on concrete properties in Nagpur, Maharashtra. The study also highlights the fact that by properly disposing of these waste materials, the environmental impact of using coconut fibres and rice husk ash in concrete can be reduced. Ali et al. [2] conducted research in New Zealand to evaluate the mechanical and dynamic features of coir fiber-reinforced concrete (CFRC) elements. Gupta, M [9] examines how nano silica and coir fibre affect concrete compressive strength and abrasion resistance. This study included 0.25%, 0.5%, and 0.75% Coir fibre by weight of fine aggregates, 2% and 3% nano silica, and 15% fly ash to partially substitute cement in the concrete mixture. Syed, H [16] testing with coconut fiber mesh from pre-defined dimensions examined how fiber form affects strength. Trial and error revealed the optimal amount of treated fiber yarn and raw fiber nets and the maximum super plasticizer needed for basic operability in concrete with regular cement and coconut fibers. Yashwanth, M. K. [18] conducted experimental investigation and obtained the maximum compressive strength for a mix having a fibre length of 15 mm and 0.2% of coir fibre content. Ali et al. [3] examines the previous findings on coir fibre reinforcement in cementitious materials the literature on coir-reinforced composites for civil engineering applications is summarised and research gaps identified.

Experimental Work and Methodology

The objective of this investigation is to do experimental investigations to improve the characteristics of concrete by including coir natural fiber as a reinforcement material. In order to accomplish this purpose, the following goals have been identified:

- To incorporate the coir (white hue) into the concrete.
- To investigate the impact of varying fiber content on the strength characteristics of concrete.
- To analyse the compressive strength of concrete (M20 grade) using cubes with fiber content percentages of 1%, 1.5%, and 2% over different time intervals (3 days, 7 days, and 28 days) for varied water-cement ratios (0.45, 0.43, and 0.5).
- To evaluate the compressive strength in comparison to plain cement concrete.

2.1 Materials used

The materials utilised in this investigation consisted of conventional portland cement, coarse aggregate comprising crushed rock with a maximum size of 20 mm and down coarse aggregate, fine aggregate

comprising clean river sand, and portable water. The coir fiber, which is readily accessible, was extracted from the waste stream and transformed into fibers with the desired length and diameter. The specific characteristics are provided in the following sections.

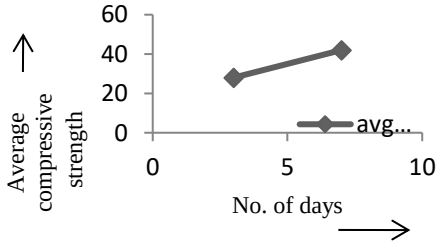
Figure 2: Image of coconut coir used as reinforcement

2.2 Compressive strength of concrete

As per the IS-456:2000, the average values obtained from testing three samples of standard-sized concrete cubes (15 cm x 15 cm x 15 cm) using a Compression Testing Machine at 7 and 28 days are presented in the table below.

Table 2.1: Compressive Strength Tests Result

Age in days	Date of casting	Date of testing	Load in KN	Area in cm^2	Compressive strength in Mpa	Average compressive strength in Mpa	Required compressive strength in Mpa
3	17/01/15	20/01/15	140	50	28	28	23
			137	50	27.5		
			142	50	28.5		
7	17/01/15	24/01/15	200	50	40	42	33
			210	50	42		
			220	50	44		



Graph 1: Average compressive strength of cement

2.3 Mix Program

In order to study the interaction of natural Fibers (coir Fiber) with concrete of different w/c ratio under compression, 108 cubes were casted respectively. The experimental program was divided into four test series. Each series of test group consists of 27 cubes of 15cm×15cm×15cm respectively.

- The first series of test is the plain concrete with 0% Fiber coir of w/c ratio 0.43, 0.45, 0.5 respectively.
- The second test series consisted of 1% of Fiber coir by volume of cement with w/c ratio 0.43, 0.45, 0.5respectively.
- The third test series consisted of 1.5% of Fiber coir by volume of cement with w/c ratio 0.43, 0.45, 0.5 respectively.
- The fourth test series consisted of 2% of Fiber coir by volume of cement with w/c ratio 0.43, 0.45, 0.5 respectively.

2.4 Compression test of concrete added with and without coir fiber

In compliance with IS 516-1959, we ran these tests. The compressive strength of concrete was measured using standard-size 150mm cubes. The specimens were loaded at a constant rate of 140

Kg/cm2 per minute until the collapse of the cube and then removed from the bearing surface of the UTM, which has a capacity of 100 tonnes without eccentricity. Compressive strength was determined by recording the peak load. Below is a tabulation of the findings.

Table2.2: Compression test values of M20 grade Cement Concrete at 3, 7 and 28 days curing:

Sl. No	w/c ratio	Avg. compressive strength (Kg/cm^2)		
		3days	7days	28days
1	0.43	136.60	191.11	266.67
2	0.45	124.44	167.41	254.81
3	0.5	103.70	122.96	210.37

Table 2.3 Compression test values of M20 grade Cement Concrete with 1%fiber at 3, 7 and 28 days curing:

SL.No	w/c ratio	Avg. compressive strength (Kg/cm^2) @ 1% Fiber		
		3days	7days	28days
1	0.43	144.63	202.96	278.52
2	0.45	134.81	177.78	257.78
3	0.5	118.52	145.19	225.19

Table 2.4 Compression test values of M20 grade Cement Concrete with 1.5% Fiber at 3,7 and 28 days curing:

SL.No	w/c ratio	Avg. compressive strength (Kg/cm^2) @ 1.5 % Fiber		
		3days	7days	28days
1	0.43	160.00	216.30	284.44
2	0.45	145.19	198.52	265.19
3	0.5	127.41	158.52	231.11

Table 2.5 Compression test values of M20 grade Cement Concrete with 2% fiber at 3 days curing:

SL.No	w/c ratio	Avg. compressive strength (Kg/cm^2) @ 2 % Fiber		
		3days	7days	28days
1	0.43	167.41	228.15	293.33
2	0.45	151.11	210.37	269.63
3	0.5	143.70	170.37	238.52

Results and discussions

This chapter demonstrates the test results. It includes the comparative tables and graphs among different w/c ratio, % of Fiber coir and average compressive strength of concrete at 28 days respectively.

Table: 3.1 compression test values of M20 grade coir Fiber reinforced concrete of 0.43 w/c ratio at 28 days curing:

Sl No.	% of Fiber	Trial mix	Load in KN	Area in cm²	Compressive strength in Kg/cm²	Avg. Compressive strength in Kg/cm²
1	0%	1	630	225	280.00	266.67
		2	590	225	262.22	
		3	580	225	257.78	
2	1%	1	630	225	280.00	278.52
		2	660	225	293.33	
		3	590	225	262.22	
3	1.5%	1	640	225	284.44	284.44
		2	620	225	275.56	
		3	660	225	293.33	
4	2%	1	660	225	293.33	293.33
		2	680	225	302.22	
		3	640	225	284.44	

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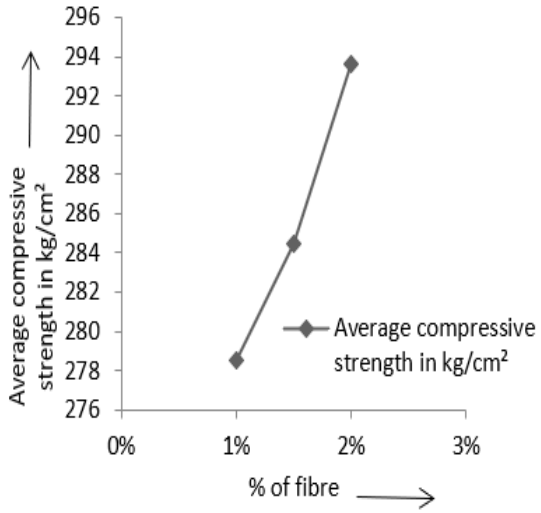
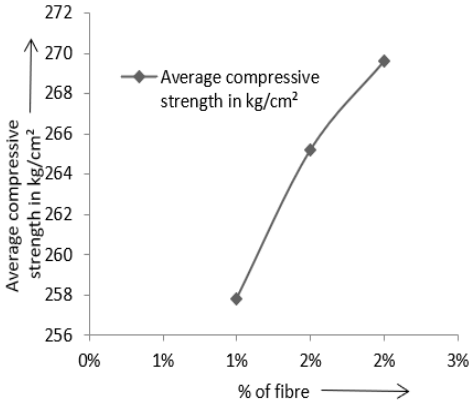


Graph 3.1 Comparison of Compressive Strength of concrete of w/c ratio 0.43 at 28 days curing.

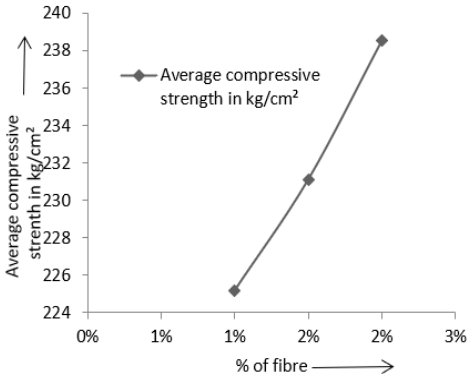
Compressive strength of coir fiber after 28 days, with 1%, 1.5%, and 2% addition shown in Graph.3.1. The strength of all three mixtures is shown to increase as time passes in the figure. Anggraini et al. [1] also observed the same pattern of the strength behaviour.The maximum compressive strength of any given mix is increased by 2% when coir Fiber is added at a water-cement ratio of 0.43. After 28 days of curing, the compressive strength of a typical concrete specimen is 266.67kg/cm2. However, the concrete specimens with coir fiber had compressive strengths of 278.52 kg/cm2, 284.44 kg/cm2, and 293.33 kg/cm2.

Table: 3.2 Compression test values of M20 grade coir Fiber reinforced concrete of 0.45 w/c ratio at 28 days curing:

Sl No.	% of Fiber	Trial mix	Load in KN	Area in cm²	Compressive strength in Kg/cm²	Avg. Compressive strength in Kg/cm²
1	0%	1	580	225	257.78	254.81
		2	550	225	244.44	
		3	590	225	262.22	
2	1%	1	580	225	257.78	257.78
		2	570	225	253.33	
		3	590	225	262.22	
3	1.5%	1	600	225	266.67	265.19
		2	580	225	257.78	
		3	610	225	271.11	
4	2%	1	610	225	271.11	269.63
		2	580	225	257.78	
		3	630	225	280.00	



Graph 3.2 Comparison of Compressive Strength of concrete of w/c ratio 0.45 at 28 days curing.



Graph 3.3 Comparison of Compressive Strength of concrete of w/c ratio 0.5 at 28 days curing

The deviation in the 28-day compressive strength of coir fiber with varying addition percentages—1%, 1.5%, and 2%—is displayed in graph 3.2. It has been noted that as the three mixes age, their strengths all show an increase. The maximum compressive strength of the mixture is increased by 2% of coir fiber in a 0.45 water cement ratio. After 28 days of curing, the standard concrete specimen demonstrates a compressive strength of 254.81 kg/cm2. However, the compressive strengths of the concrete specimen made of coir fiber are 257.78 kg/cm2, 265.18 kg/cm2, and 269.68 kg/cm2, respectively. Table 4.2 confirms that the strength enhancement after 28 days of curing for both plain concrete and coir fiber concrete in a 0.45 water cement ratio is not significantly different.

Table 3.3: Compression test results at 28 days of curing for M20 grade Coir Fiber reinforced concrete with a 0.5 w/c ratio

Sl No.	% of Fiber	Trial mix	Load in KN	Area in cm²	Compressive strength in Kg/cm²	Avg. Compressive strength in Kg/cm²
1	0%	1	480	225	213.33	210.37
		2	450	225	200.00	
		3	490	225	217.78	
2	1%	1	530	225	235.56	225.19
		2	480	225	213.33	
		3	510	225	226.67	
3	1.5%	1	520	225	231.11	231.11
		2	500	225	222.22	
		3	540	225	240.00	
4	2%	1	540	225	240.00	238.52
		2	520	225	231.11	
		3	550	225	244.44	

Graph 3.3 illustrates the change in compressive strength of coir fiber after 28 days at three different addition percentages (1%, 1.5%). The strength of all three mixtures is shown to increase as time passes in the figure. Maximum compressive strength is improved when coir Fiber, at a rate of 2%, is added to a mixture with a water-cement ratio of 0.5. The compressive strength of the standard concrete specimen after 28 days of curing is 210.37kg/cm2. However, 225.19Kg/cm2, 231.11Kg/cm2, and 238.52kg/cm2 are their respective compressive strengths as shown by the coir Fiber concrete specimen.

3.2 Compressive strength

From the result obtained, it is clear that compressive strength of concrete is maximum when the Fiber contained is 2% of the cement.

Table: 3.4 Behaviour of compressive strength of plain concrete and concrete with various percentages of coir Fiber of 0.43 w/c ratio after 28days of curing:

Compressive strength of Plain concrete in Kg/cm²	% of coir Fiber	% increase in strength
0%: 266.67	1%: 278.52	4.44%
	1.5%: 284.44	6.67%
	2%: 293.33	9.9%

Table: 3.5 Behaviour of compressive strength of plain concrete and concrete with various percentages of coir Fiber of 0.45 w/c ratio after 28days of curing:

Compressive strength of Plain concrete in Kg/cm²	% of coir Fiber	% increase in strength
0%: 254.81	1%: 257.78	2.16%
	1.5%: 265.19	4.07%

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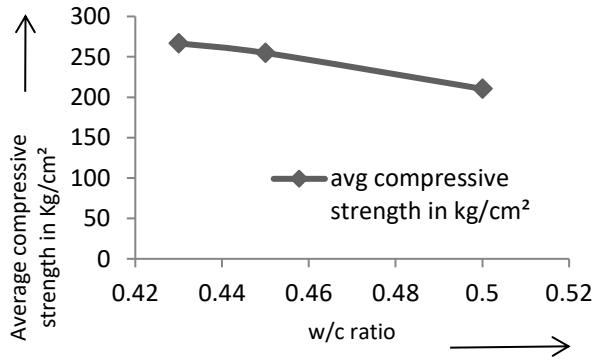
	2%: 269.63	5.81%

Table: 3.6 Behaviour of compressive strength of plain concrete and concrete with various percentages of coir Fiber of 0.5 w/c ratio after 28days of curing:

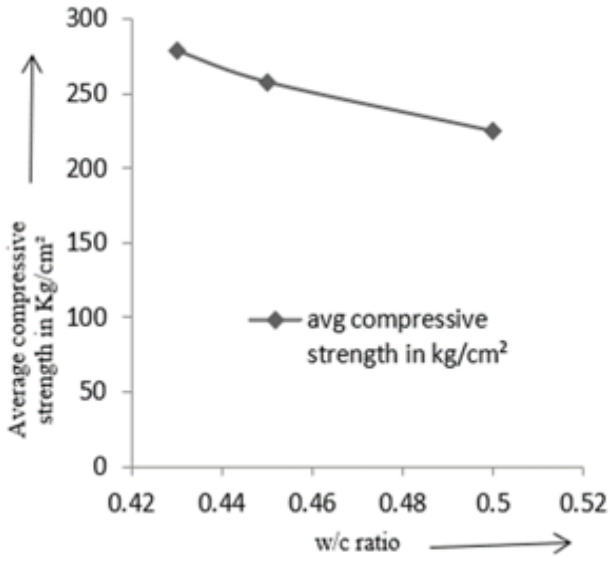
Compressive strength of Plain concrete in Kg/cm²	% of coir Fiber	% increase in strength
0%: 210.37	1%: 225.19	1.01%
	1.5%: 231.11	2.85%
	2%: 238.52	4.38%

From the table it is clear that the strength of CFRC with 0.43w/c ratio has increased by 7.03% for compression compared to the plain concrete.

3.3 Comparison graph between w/c ratio and average compressive strength of concrete at 28 days curing:



The relationship between the compressive strength of plain concrete and the water-to-cement ratio after 28 days of curing is depicted in Graph 3.4. All the mixtures with varying w/c ratios show an increase in strength as curing time progresses. The compressive strength of plain concrete with a 0.43 w/c ratio is the highest of any mix type and any age. At 28 days after curing, the compressive strength of a plain concrete specimen ranges from 266.67 kg/cm2 to 254.81 Kg/cm2 with a w/c ratio of 0.43 to 210.37 Kg/cm2 with a w/c ratio of 0.50.



Graph 3.5 Comparison of Compressive Strength of concrete (with mixing of 1% Fiber coir) at 28 days curing.

Compressive strength of plain concrete versus water-to-cement ratio at 28 days of curing (Graph 3.5). All the mixtures with varying w/c ratios show an increase in strength as curing time progresses. Coir Fiber Concrete with a 0.43 w/c ratio has the highest compressive strength across the board. The coir fiber concrete specimen reaches compressive strengths of 278.52 kg/cm2, 257.78 kg/cm2, and 225.19 kg/cm2 after 28 days of curing, using water-to-cement ratios of 0.43, 0.45, and 0.50, respectively. After 28 days, the coir fibrous concrete, which contains a 1% coir mixture, exhibits a strength improvement of 4.44%, 2.16%, and 1.01% compared to the plain concrete with water-to-cement ratios of 0.43, 0.45, and 0.50, respectively.

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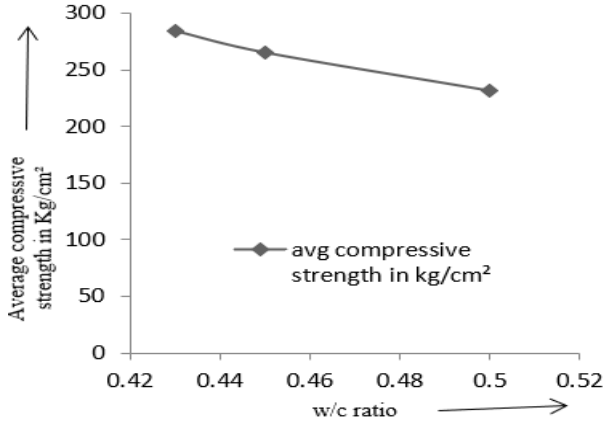
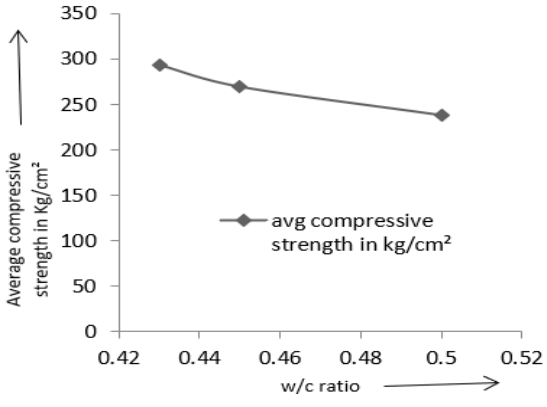


Graph 3.6 Comparison of Compressive Strength of concrete (with mixing of 1.5% Fiber coir) at 28 days curing.

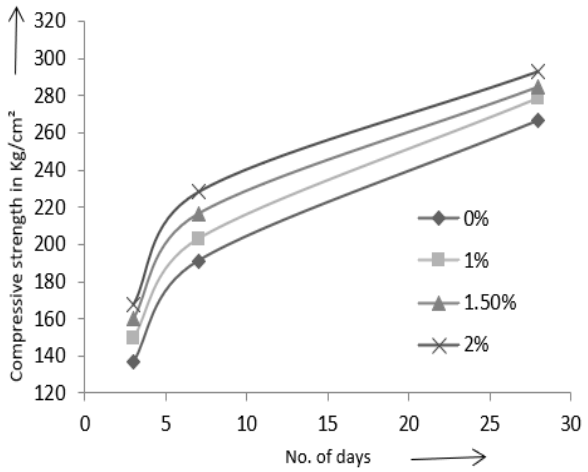


Graph 3.7 Comparison of Compressive Strength of concrete (with mixing of 2% Fiber coir) at 28 days curing.

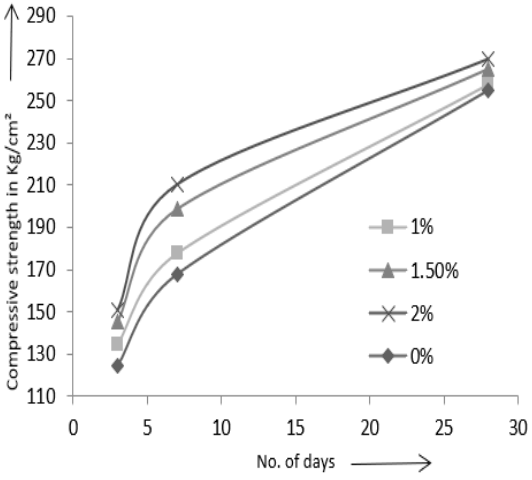
Compressive strength versus water-to-cement ratio in plain concrete after 28 days of curing is depicted in Graph 4.6. It can be seen in the figure that the strength of all the mixtures, regardless of their initial w/c ratio, improves as time passes. Compressive strength remains high throughout the ageing process for coir Fiber concrete with a 0.43 w/c ratio. At 28 days of curing, the compressive strength of the coir Fiber concrete specimen is 284.44 kg/cm2, 265.19 Kg/cm2, and 231.11 Kg/cm2 for a w/c ratio of 0.43, 0.45, and 0.50, respectively. At 28 days old, coir fibrous concrete with a 1% coir mix shows a 6.67 percent, 4.07 percent, and 4.38% strength increase over plain concrete with a w/c ratio of 0.43, 0.45, and 0.50, respectively.

Compressive strength versus water-to-cement ratio in plain concrete after 28 days of curing is depicted in Graph 3.7. All the mixtures with varying w/c ratios show an increase in strength as curing time progresses. Compressive strength remains high throughout the ageing process for coir Fiber concrete with a 0.43 w/c ratio. The compressive strengths of the coir fiber concrete specimen were tested as 293.33 kg/cm2, 268.63 kg/cm2, and 238.52 kg/cm2 after 28, 21, and 14 days of curing, respectively. The water-to-cement ratio for each measurement was 0.43, 0.45, and 0.50. At 28 days old, coir fibrous concrete with a 1% coir mix shows a 9.9%, 5.81%, and 2.85% strength increase over plain concrete using water-to-cement ratios of 0.43, 0.45, and 0.50, respectively.

3.4 Comparison Graph between Age of Curing and Compressive Strength of Concrete of Different % of Fiber Content:



Graph 3.8 Comparison of Compressive Strength of concrete of 0.43 w/c ratio.



Graph 3.9 Comparison of Compressive Strength of concrete of 0.45 w/c ratio.

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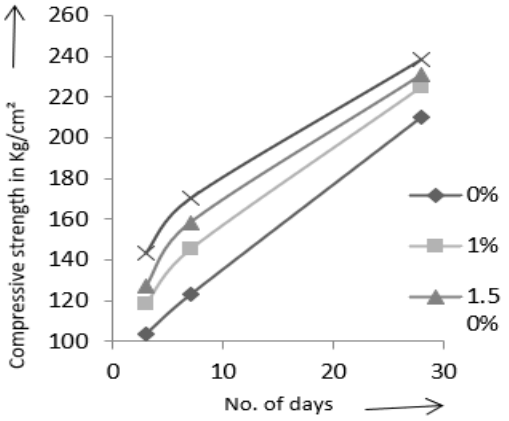

Graph 3.10 Comparison of Compressive Strength of concrete of 0.50 w/c ratio.

The variation in plain concrete's compressive strength and various percentages of fiber content versus the curing age is presented in Graphs 3.8, 3.9, and 3.10. It has been noted that throughout the curing age period, the strength of all mixes with varying percentages of fiber content increases. The coir fibrous concrete mix with a 2% fiber content has the highest compressive strength of all the mixes over all ages.

Conclusion

The results of laboratory tests conducted on concrete reinforced with coir fibers are presented. The following deductions are possible. As was to be expected, the addition of coir Fibers reduced the compressive strength because of difficulties in compaction, which increased voids. Although coir Fiber as an additive to concrete has many desirable qualities, it is not likely to replace steel in most construction projects. Natural Fiber enhancement has been shown to be a viable and cost-effective alternative to traditional building materials in a number of experimental and demonstration projects around the world. Because of its low density, Coir Fiber can be used in Fiber Reinforced Concrete to create a structurally light weight material. Coir Fibers, which are widely available, can be used to strengthen concrete and thereby cut down on waste. Compressive strength of coir Fiber reinforced concrete is maximised at 2% addition of coir Fiber by weight of cement for w/c ratio 0.43, 0.45, 0.5 respectively, as shown by experimental results and observations in all cases. The results show that the compressive strength increases by 9.9% compared to plain concrete at a w/c ratio of 0.43, by 5.81% compared to plain concrete at a w/c ratio of 0.45, and by 4.38% compared to plain concrete at a w/c ratio of 0.50. Because of the Fiber bridging effect, it is determined that incorporating coir Fiber into concrete causes the failure mode to shift from brittle to ductile. Incorporating coir Fiber into the composite material improves its ductility and strength. To increase the use of these eco-friendly concrete structures, however, the durability of coir Fiber reinforced concrete must be enhanced.

References

[1] Anggraini, V., Asadi, A., Huat, B. B., & Nahazanan, H. (2015). “Effects of coir fibers on tensile and compressive strength of lime treated soft soil. Measurement”, 59, 372-381.
[2] Ali, M., Li, X., & Chouw, N. (2013). Experimental investigations on bond strength between coconut fibre and concrete. Materials & Design, 44, 596-605.
[3] Ali, B., Hawreen, A., Kahla, N. B., Amir, M. T., Azab, M., & Raza, A. (2022). A critical review on the utilization of coir (coconut fiber) in cementitious materials. Construction and Building Materials, 351, 128957.
[4] Banthia, N., & Yan, C. (2000). Shrinkage cracking in polyolefin fiber-reinforced concrete. Materials Journal, 97(4), 432-437.
[5] Bilba, K., Arsène, M. A., & Ouensanga, A. (2003). Sugar cane bagasse fibre reinforced cement composites. Part I. Influence of the botanical components of bagasse on the setting of bagasse/cement composite. Cement and concrete composites, 25(1), 91-96.
[6] Das, N. G., Talukdar, P. K., Kalita, J., Baruah, I., & Sribastava, R. B. (2007). Malaria situation in forest-fringed villages of Sonitpur district (Assam), India bordering Arunachal Pradesh during an outbreak. Journal of vector borne diseases, 44(3), 213.

[7] Domke, P. V., & Mude, V. D. (2015). Natural fiber reinforced building materials. IOSR Journal of Mechanical and Civil Engineering, 12(3), 2320-2334.
[8] Gunasekaran, K. P. S. K., & Kumar, P. S. (2008, February). Lightweight concrete using coconut shells as aggregate. In Proceedings of the ICACC-2008. International conference on advances in concrete and construction, Hyderabad, India (pp. 7-9).
[9] Gupta, M., & Kumar, M. (2019). Effect of nano silica and coir fiber on compressive strength and abrasion resistance of concrete. Construction and Building Materials, 226, 44-50.
[10] Methods of Tests for Strength of Concrete. IS: 516-1959, Bureau of Indian Standards, New Delhi.
[11] Noor Md. SadiqulHasan, HabiburRahmanSobuz, Md. ShibleeSayed and Md. Saiful Islam (2012). "The Use of Coconut Fiber in the Production of Structural Lightweight Concrete".Journal of Applied Sciences, pp. 831-839.
[12] O.P.Baruah and S.A.Talukdar, (2007) "A comparative study of compressive, flexural, tensile and shear strength of concrete with fibres of different origins," Indian Concrete Journal, Vol. 81, No. 7, pp. 17-24.
[13] Ramakrishna, G., and Sundararajan, T. (2005). "Impact strength of a few natural Fiber reinforced cement mortar slabs: A comparative study."Cement and Concrete Composites, pp. 547-553.
[14] Reis, J. M. L. (2006). Fracture and flexural characterization of natural fiber-reinforced polymer concrete. Construction and building materials, 20(9), 673-678.
[15] Romildo, D., Toledo, F., Karen, S.,England, G. L. and Ghavami, K., (2003) "durability of alkali-sensitive sisal and coconut Fibers in cement mortar composite, Cement and concrete composite", 22, (2), 2000, pp. 127-143.
[16] Syed, H., Nerella, R., & Madduru, S. R. C. (2020). Role of coconut coir fiber in concrete. Materials Today: Proceedings, 27, 1104-1110.
[17] Yalley, P. P. and Kwan, Alan ShuKhen (2009). "Use of coconut Fiber as an enhancement of concrete". Journal of Engineering and Technology 3, pp. 54-73.
[18] Yashwanth, M. K. (2021). Evaluation of Compressive Strength of Coir Fibre Reinforced Concrete. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(10)