ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

Experimental Study on Strength of 2% Coir Fiber Recycled Concrete

Xianpeng Wang, Leonovich S. N, Kovshar S. N

Belarusian national technical University, Minsk, Belarus

Abstract

In this paper, concrete specimens are made by adding 2% coir fiber to concrete. The simulated beam and simulated column components were tested, and the experimental data were analyzed and studied. The results showed that the addition of 2% coir fiber was beneficial to enhance the flexural and axial compressive strength of concrete. Therefore, coir fiber can be used in buildings as a green pure natural plant fiber. A certain amount of coir fiber can not only meet the mechanical design requirements of buildings, but also is an excellent natural material for the development of green and pollution-free building materials.

Keywords

2% Coir Fiber; Concrete; Flexural Test; Compressive Test; Green Building Materials.

1. Introduction

Since the last century, scientists in China and all over the world have made in-depth research on natural plant fibers. Natural plant fibers have a long history in green buildings as a concrete reinforcement substrate. Many scholars have studied adding sisal fiber to concrete and found that the stress strength of sisal fiber concrete is better than that of ordinary concrete. Many scholars have also studied the physical and mechanical properties of straw fiber concrete, indicating the role of straw fiber in concrete. Of course, many scientists have conducted research on bamboo fiber reinforced concrete. However, at this stage, scholars from various countries have little research on coconut husk fibers. Chinese scholar Wang Wei et al. [1] studied the effect of alkali treatment on the morphological structure of coconut husk fibers. P.M.Katkar et al. [2] found that the boiled coir fiber nonwoven reinforced cement board is very good in terms of heat resistance, flexural strength and compressive strength. Pusit Lertwattanaruk and Anchisa Suntijitto. [3] conducted relevant experimental research on coir fiber and oil palm fiber cement mortar. The results show that coir fiber has poor heat transfer performance in composite building materials based on natural fibers, and has excellent building energy efficiency. Coir fiber has a certain tensile strength and can be used as a plant fiber reinforced material for the cement mortar matrix, which is expected to improve the flexural strength of the cement matrix and improve the brittle failure properties. The addition of coir fiber can reduce the use of sand and gravel in concrete, reduce the density, and prepare lightweight filling materials with better comprehensive mechanical and physical properties [4]. Coir fiber is 350 mm long, 0.12 – 0.25 mm in diameter, and has a density of 1250 kg/m3. Coconut fiber has one of the highest amounts of lignin coating, which makes it stronger than most other types of natural fibers [5]. Coir and sisal fibers are renewable natural fiber materials that enhance the growth and sustainability of the construction industry. They can improve the properties of concrete. Majid Ali et al. [6] discussed coconut fiber reinforced concrete and concluded that the properties vary with fiber length and the strength of CFRC can be higher or lower compared to normal concrete. Tests have also confirmed that coconut fibers in concrete can improve its flexural toughness. Zhang Xiaoxiao and Leo Pel [7] studied the effect of coir fiber on the hydration and shrinkage of cement-based materials on concrete. After adding coir

 Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0135

fiber to concrete, the drying shrinkage rate of LWAC increased and the self-shrinkage rate decreased. Fibers enhance the strength and toughness of LWAC. Research by Rajan Shikha et al. [8] showed that coconut fibers play a key role in limiting the formation and propagation of curved cracks. The optimum level of improving the flexural strength, tensile strength, compressive strength and other properties of concrete with different volume fractions of coconut fiber is 2%, not more than 3%. N Kaarthik Krishna, M Prasanth, R Gowtham et al. evaluated the effectiveness of natural fiber reinforced concrete by taking the performance of plain concrete as a reference index. It has been proved that 2% of natural fibers can effectively improve the ductility and axial compressive strength of concrete [9]. Therefore, this paper studies the effect of adding 2% coconut fiber on the flexural strength of concrete simulated beams and the compressive strength of concrete simulated columns.

2. Experimental Studies

2.1 Experimental Materials

Coir fiber: Coir fiber is a by-product of coconut palm fruit, which is obtained by etching or mechanical processing of coconut shell in seawater. The diameter is generally 100~450 μm, the length is 10~25 cm, and the density is 1.12 g/m3. In this test, it is cut into a length of about 10 mm, and the coir fiber is soaked in 4% NaOH, washed with distilled water, and then placed in Dry in an oven at 60 °C for 8 h.

The coarse aggregate is divided into recycled coarse aggregate and natural coarse aggregate; the natural coarse aggregate is ordinary crushed stone, and the recycled coarse aggregate is crushed and sieved by the concrete beam (original strength is C30) after the laboratory test. As a result, the particle size of the coarse aggregate is 20-30 mm, and the gradation is continuous. The fine aggregate is the natural river sand of the Minsk Sea. According to the standard of sand and stone quality and inspection method for ordinary concrete, the basic properties of natural coarse aggregate and recycled coarse aggregate are measured as shown in Table 1.

Table 1. Basic properties of aggregates

	Particle size/mm	Apparent density kg/m3	Bulk density kg/m^3	Mud content /%	Water absorption/%	Crush indicator/%
Recycled coarse aggregate	20-30	2460	1202	0.60	4.8	16.3
Natural coarse aggregate	20-30	2703	1450	0.54	0.43	17.15
Sand	-	2625	1638	0.25	-	-

High-efficiency water-reducing agent: buy high-efficiency water-reducing agent that meets the standards in the Belarusian building materials market, and its performance and technical indicators are shown in Table 2.

Table 2. Related indicators of superplasticizers

Water reduction rate /%	Solid content /%	Density g/mL	Chloride content /%	Cement slurry fluidity /mm
26	35	1.12	0	230

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

Cement: P·O 42.5 grade Portland cement was used as the cementitious material in the test; in Table 3, the standard GB 175-2020 "General Portland Cement" was used, and all parameters met the quality index requirements specified in the standard.

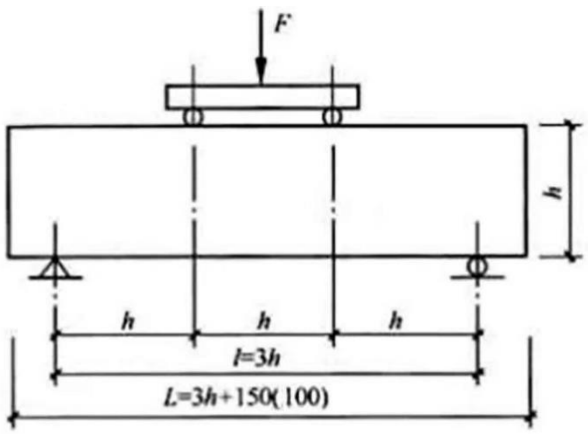
Table 3. P·O 42.5 Grade cement parameter index

Fineness /%	Standard consistency water consumption /%	Coagulation time /min		Flexural strength /MPa		Compressive strength /MPa	
		Initial setting	Final coagulation	3 d	28 d	3 d	28 d
1.95	26.70	160	280	5.5	9.0	23.6	48.8

2.2 Experimental Design

In this experiment, the size of the heavy concrete specimen is 100*100*400mm and 100*100*100mm. The curing conditions: 28d, (20±3°C) humidity 90%±5%. Material dosage: P·O 42.5 Poland Special cement 400kg/m3 - 3.5kg fine sand 730kg/m3 - 7.1kg, coarse aggregate 1100kg/m3 - 11.0kg, water 180L/m3 - 1.8L, water-cement ratio 0.5, coconut fiber 50kg/m3 - 0.4kg (2%). Mixing methods Dry mixing and wet mixing were used to mix coir fiber and pour coir fiber concrete specimens.

The simulated beam bending and compression experiment adopts two ends hinged (spacing 300mm), and there is a concentrated load force on each side (spacing 100mm) with the 200mm position of the test block as the center (Fig. 1). The simulated column is compressive, the upper and lower compression dimensions are 100*100, and the compression area is 10000m3. The compression surface is not coated with lubricant. The force analysis diagram of the column is shown in Fig. 2.



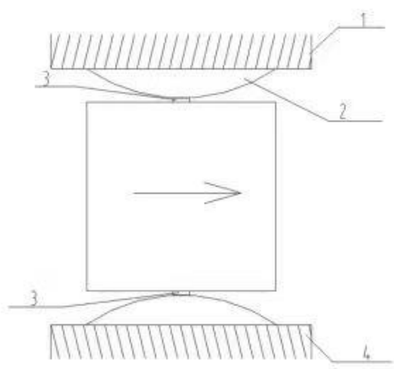


Fig. 1 Force analysis diagram of beam specimen **Fig. 2** Force analysis diagram of column specimen

3. Test Data Results and Analysis

3.1 Experimental Comparative Analysis of Concrete Mixing Methods

The beam simulation test was carried out on the coir fiber reinforced concrete specimens with wet mixing and dry mixing respectively. The size of the specimens was (40*40*160mm), and the data were recorded and analyzed. The test data are shown in Table 4.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

Table 4. Compressive strength data of specimens with different mixing methods

Mixing method	Compressive strengthMpa	Average value
Dry mix	4.87	5.59
	5.3	
	6.62	
Wet mixing	5.52	5.21
	5.2	
	4.91	

Fig. 3 Compression section of fiber wet-mixed specimen

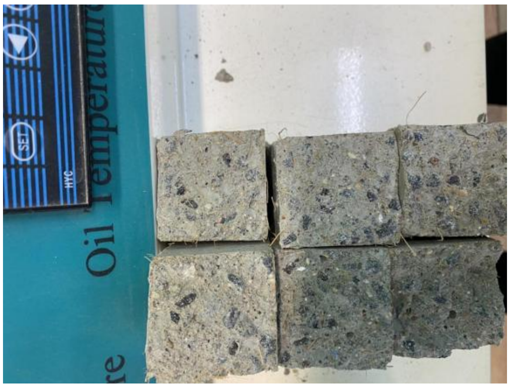


Fig. 4 Compression section of fiber dry-mixed specimen

Compared with the experimental data, dry mixing is 6.8% higher than wet mixing. From the cross-section, wet mixing will lead to uneven distribution of coir fibers (Fig. 3), and the fibers are aggregated, which will lead to a certain probability of failure of components. And seriously affect the safety of the project, there are hidden dangers, so the best mixing method of fiber dry mixing should be used as the material. The compression section of the dry-mixed specimen is shown in (Fig. 4).

3.2 Comparative Test Analysis of Flexural Strength of Coir Fiber Reinforced Concrete Simulated Beams

Majid Ali, Nawawi Chouw conducted a tensile test of coconut fiber rope embedded in concrete considering many factors such as the length of the coir fiber rope embedded, rope diameter, pretreatment conditions, concrete mix ratio, fiber content and the elongation of the coconut fiber rope. Research. Research has shown that coconut fiber rope is a construction material for reinforced concrete (CFRC), and the coconut fiber rope is embedded in the foundation and top tie beams by

 Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0135

anchoring. Its tensile strength to concrete is important to the overall stability of the proposed structure.It can enhance the axial pull-out performance and tensile capacity of concrete [10].

Using the KBLS-300 precision flexural strength analyzer, the flexural test of ordinary concrete and coir fiber concrete with a size of 100*100*400mm was carried out. And according to the concrete physical and mechanical properties test method standard GB/T50081-2019 flexural strength calculation formula (1), calculate the relevant data, get Table 5.

$$f_f = \frac{Fl}{bh^2} \tag{1}$$

f_f-Concrete flexural strength (MPa) accurate to 0.01.

F-the failure load of the specimen (N).

L-span between supports (mm).

h-section height of specimen (mm).

b-section width of specimen (mm).

Table 5. 100*100*400mm Flexural test results of simulated beam specimens

28-day Beam flexural test results of ordinary concrete specimens(100*100*400mm)					
Number	LC1	LC2	LC3	Total	Average value
KN	11.503	15.140	15.278	41.921	13.974
MPA	3.451	4.542	4.583	12.576	4.192
28-day Flexural test results of beams with coir fiber concrete(100*100*400mm)					
Number	LCF1	LCF2	LCF3	Total	Average value
KN	14.429	16.533	16.556	47.518	15.839
MPA	4.329	4.96	4.967	14.256	4.752

Fig. 5 Flexural test of ordinary concrete beam members

Fig. 6 Flexural test of coir fiber reinforced concrete beam

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0135

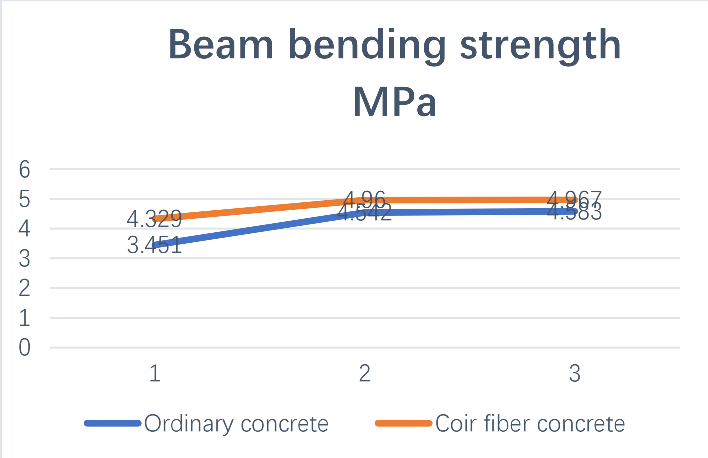


Fig. 7 Simulated beam stress line diagram

From the above test data and the flexural test diagram of beam members, it can be obtained that the average flexural strength of the non-coconut fiber concrete test block is 4.192MPa. When the member reaches the maximum bearing capacity, the cracks are generated from the bottom and rapidly extend along the cross-section to the top, thus breaking. In two sections (Fig. 5) at this time, the stress and strain ($\sigma = \varepsilon$) of the concrete member has fewer pre-break signs. Observe that the coarse aggregate is evenly distributed on the fractured section. (Fig. 8) The average flexural strength of the soil mixed with coir fiber concrete is 4.752MPa. When the component reaches the maximum bearing capacity, the crack slowly extends from the bottom of the component to the upper part and down, and the component is not broken at this time. Two sections, any coconut shreds are connected at the cross-section (Fig. 6). At this time, the strain is less than the strain ($\sigma < \varepsilon$), and the failure of the concrete member is larger. After the failure, the member has not broken, and can still bear a small load. It was observed that the distribution of coarse aggregate in the fractured section was uniform, and the distribution of coir fiber was uniform (Fig. 9). Therefore, the concrete added with 2% coir fiber is beneficial to improve the strength of concrete, and can be used in green building projects.

Fig. 8 Cross-section of flexural specimen of ordinary concrete beam

Fig. 9 Cross-section of flexural specimen of coir fiber reinforced concrete beam

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0135

3.3 Comparative Analysis of Compressive Strength of Coir Fiber Reinforced Concrete Simulated Columns

Bhupendra Kumar et.al [11] . studied the effect on concrete by adding fly ash and coconut coir fibers together to enhance the performance of concrete. Experiments show that 10% and 20% cement replacement by adding fly ash and adding 1.5%, 2% by weight of coconut fiber can improve the workability and compressive strength of concrete as well as concrete properties. In this experiment, the DS2-1000N compressive strength tester was used to conduct a simulated column compressive test on ordinary concrete and 2% coconut fiber concrete. The size of the specimen was 100*100*100mm. The compressive strength data of the obtained specimens are shown in Table 6.

Table 6. 100*100*100mm Simulated column test results

28-day Pillar axial compression test results of ordinary concrete specimens（100*100*100mm）								
Number	ZC1	ZC2	ZC3	ZC4	ZC5	ZC6	Total	Average value
KN	345.384	324.739	350.563	305.218	368.72	367.045	2061.669	343.612
MPA	34.538	32.474	35.056	30.522	36.872	36.705	206.167	34.361
28-day Pillar axial compression test results of the coir fiber concrete specimens（100*100*100mm）								
Number	ZCF1	ZCF2	ZCF3	ZCF4	ZCF5	ZCF6	Total	Average value
KN	354.125	369.338	369.34	351.205	352.467	352.47	2149.316	358.219
MPA	35.412	36.934	35.141	35.12	35.247	35.247	216.404	36.067

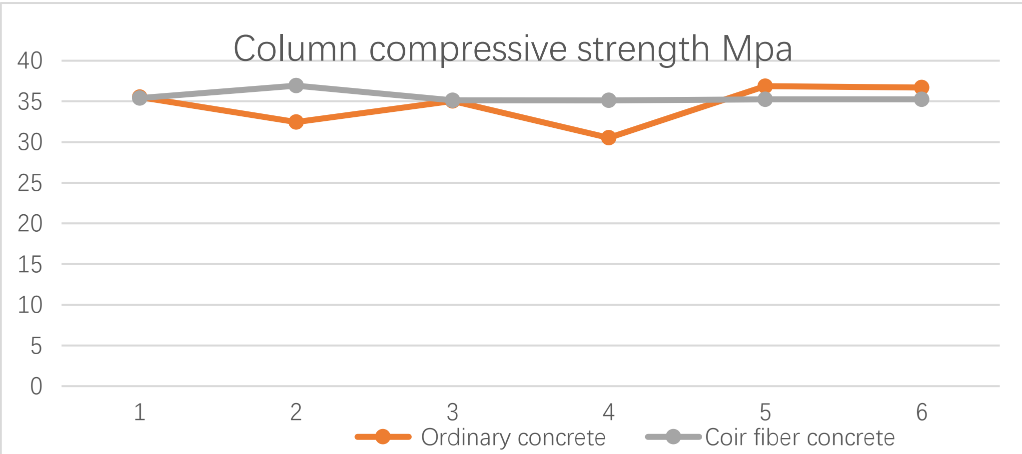


Fig. 10 Compression force diagram of the simulated axial center of the column

Based on the axial compressive test data, and following the "Code for Design of Concrete Structures GB50010---2010", the standard value of cube compressive strength fcu,k calculation formula (2).

$$f_{cu.k} = \mu_f - 1.645\sigma_f \tag{2}$$

μ_f - average value σ_f - squared difference

According to the test data in Table 6, the average value of the ultimate compressive endurance of the concrete block without coir fiber is 343.612KN. The average value of the ultimate compressive endurance of the soil mixed with the coir fiber concrete is 358.219KN. The standard compressive value of the block is: 30.64 N/mm2, and the standard compressive value of the coir fiber concrete cube is: 35.21 N/mm2. Therefore, the axial compression of the concrete simulated column with 2% coir fiber is much higher than that of ordinary concrete, and the standard value of compression is

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

increased by 4.57N/mm2. It shows that the addition of coir fiber is beneficial to the compressive value of concrete, and it can be used in engineering construction.

3.4 Comparative Analysis of Elastic Modulus Test of Coir Fiber Concrete

The $\sigma-\varepsilon$ curve of concrete is an important aspect of the physical and mechanical properties of concrete, and it is an indispensable basis for determining the elastic modulus of concrete. When calculating the section stress and deformation of concrete members, the pre-compression stress of prestressed concrete members, and the internal force caused by the settlement of supports due to temperature changes, it is necessary to use the elastic modulus analysis of concrete. In general, the $\sigma-\varepsilon$ curve of compressed concrete is nonlinear, and the relationship between stress and strain is not always familiar, which leads to the problem of "modulus" value. But its stability coefficient is not easy to obtain from experiments.

Amit Rai et al. [12] described that the addition of fibers helps to improve the ductility of concrete and its load-carrying capacity after cracking. He also found that fiber reinforcement in concrete is the most important contributor to concrete flexural toughness.Therefore, according to "GB/T 50081-2019 Standard for Test Methods of Physical and Mechanical Properties of Concrete", the elastic modulus Ec value is determined in the following way: using prismatic specimens, the upper limit of stress is 0.5 f_c and repeated loading 5-10 times, due to the plasticity of concrete In nature, when the unloading is zero each time, there is residual deformation, but as the load is repeated for many times, the residual deformation gradually decreases. After repeated loading for 5-10 times, the deformation tends to be stable, and the $\sigma-\varepsilon$ curve of concrete is close.The slope of the connecting line from the origin to the corresponding point on the $\sigma-\varepsilon$ curve is the elastic modulus of the concrete.According to the statistical analysis of the experimental values of the elastic modulus of different strength grades of concrete, the empirical relationship between E_c and f_{cu} is the formula $E_c=\frac{10^5}{2.2+\frac{34.7}{f_{cu}}}$ .The elastic modulus of concrete is calculated in Table 7.

Table 7. Elastic modulus values of coir fiber concrete

Compressive elastic modulus of concrete block E_c								
Compressive elastic modulus of ordinary concrete columns								
Number	ZCF1	ZCF2	ZCF3	ZCF4	ZCF5	ZCF6	Total	Average value
f_{cu} MPA	34.538	32.474	35.056	30.522	36.872	36.705	206.167	34.361
$E_c 10^4$N/mm^2	3.120	3.059	3.135	3.00	3.184	3.180	18.678	3.113
Compressive elastic modulus of coir fiber concrete columns								
Number	ZCF1	ZCF2	ZCF3	ZCF4	ZCF5	ZCF6	Total	Average value
f_{cu}MPA	35.412	36.934	35.141	35.12	35.247	35.247	216.404	36.067
$E_c 10^4$N/mm^2	3.145	3.185	3.137	3.137	3.140	3.140	18.884	3.147

According to Table 7, the elastic modulus of concrete with 2% coir fiber is increased by 0.034 MPa compared with that of ordinary concrete, so the addition of renewable coconut fiber has little effect on the elastic modulus of concrete. But it can be used in concrete.

4. Conclusion

Using testXpert as the material static analysis software for static analysis, it is concluded that when adding renewable plant fibers to concrete, dry mixing is the best mixing method, which is conducive to the uniform dispersion of fibers and avoids the occurrence of fiber agglomeration. , which can increase the strength of concrete to a certain extent.

Adding 2% of coir fiber is beneficial to increase the flexural strength of concrete beams, and the average flexural strength is increased by 0.56MPa. In the flexural test of the beam simulation member, when the member reaches the maximum bearing capacity, the crack slowly extends from the bottom

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

of the member to the upper part and lower, and no brittle fracture occurs directly, indicating that the flexural fatigue limit of the coir fiber reinforced concrete beam can still be added. Bearing a certain force load, coir fiber can be used in the production and construction of construction beams, and it also meets the design requirements of concrete beams. Correspondingly, you can also win a certain escape time in disasters such as earthquakes.

In the experimental data of simulated column compression, it is shown that the compressive strength can be increased by 5% = 17.068KN after adding 2% of coconut fiber. Referring to the standard value of concrete strength, the standard value of compressive strength mixed with coir fiber is consistent with the standard value of C55 strength, which is 2 grades higher than the design strength grade C45. Through the concrete design principle, the strength equivalent substitution method is used for conversion, and the international HRB400 grade steel quotation in 2021 is used as an example: coconut fiber concrete can save 20 US dollars per cubic meter, which proves that it is an implementable green environmental protection material and can be used for buildings. The project saves a lot of economic costs.

According to the experimental data, the addition of 2% coir fiber increases the elastic modulus of concrete by 1.09%, indicating that the addition of coir fiber to the concrete helps to improve the ultimate bearing capacity of the material, but cannot improve the ultimate load at the end of elastic deformation. The point means that the coir fiber cannot effectively inhibit the generation of cracks. But as a plant fiber additive, it can be used in green buildings.

Acknowledgments

China Scholarship Council. Ph.D

References

[1] Wang Wei, Huang Gu.Effect of alkali treatment on the morphological structure of coconut fiber[J]. Shanghai Textile Science and Technology,2008,36(10):20-22.DOI:10.16549/j.cnki.issn.1001-2044.2008.10.007.

[2] KATKAR P M, PATIL C A, KHUDE P A, et al. Coir/Cement Composite Materials [J]. International Textile Review, 2013, 41(2): 56, 58-59.https://kns.cnki.net/kcms/detail/detail.aspx?dbcode= CJFD&dbname=CJFD2013&filename=GFZB201302026&uniplatform=NZKPT&v=BJz8XTGNVa_pVU3w5_pp6qAo7cHaw3usjwi2s7EuXT3xJKwEb47C7Q8nVLaCZzzh.

[3] Lertwattanaruk P, Suntijitto A. Properties of natural fiber cement materials containing coconut coir and oil palm fibers for residential building applications[J]. Construction and Building Materials, 2015, 94: 664-669. https://doi.org/10.1016/j.conbuildmat.2015.07.154.

[4] Pardeshi S, Gudiyawar M Y, Katkar P M. Studies on fiber-concrete composite[J]. Technical Textiles/Technische Textilen, 2013, 56(4).https://web.p.ebscohost.com/abstract?direct= true&profile=ehost&scope=site&authtype=crawler.&jrnl=03233243&AN=90420638&h=dBXeGdpRYBbUWCU3xPK12QntrpXm0FWfJKb9hemzn5KQgPxGinDBIyqF9ybTobPVtLEQ3UEVw1L0UbAMtB%2bXDA%3d%3d&crl=c&resultNs=AdminWebAuth&resultLocal=ErrCrlNotAuth&crlhashurl=login.aspx%3fdirect%3dtrue%26profile%3dehost%26scope%3dsite%26authtype%3dcrawler%26jrnl%3d03233243%26AN%3d90420638.

[5] Food and Agriculture Organization of the United Nations (FAO), Natural Fibers:Coir, International Year of Natural Fibers.Retrieved December 1, 2012 . from www.naturalfibres2009.org.

[6] Majid Ali, Anthony Liu, HouSou, and Nawawi Chouw, Mechanical and dynamic properties of coconut fiber reinforced concrete, Construction and Building Materials 30 (2012) 814-825. https://daneshyari.com/article/preview/258585.pdf.

[7] Zhang X, Pel L, Gauvin F, et al. Reinforcing Mechanisms of Coir Fibers in Light-Weight Aggregate Concrete[J]. Materials, 2021, 14(3): 699. https://doi.org/10.3390/ma14030699.

[8] RajanShikha, A.K. Saxena, A.K. Jha Evaluation of Compressive Strength of Concrete Using Coconut Coir Fiber, International Journal for Research in Applied Science & Engineering Technology (IJRASET)

ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0135

3(2015)313-317.https://1library.net/document/zke0lxez-evaluation-compressive-strength-concrete-using-coconut-coir-fibre.html.

[9] Krishna N K, Prasanth M, Gowtham R, et al. Enhancement of properties of concrete using natural fibers[J]. Materials Today: Proceedings, 2018, 5(11): 23816-23823. https://doi.org/10.1016/j.matpr.2018. 10.173.

[10] Ali M, Chouw N. Experimental investigations on coconut-fibre rope tensile strength and pullout from coconut fibre reinforced concrete[J]. Construction and Building Materials, 2013, 41: 681-690. https://doi. org/10.1016/j.conbuildmat.2012.12.052.

[11] Bhupendra Kumar, Dr. Amit Viswakarma, Dr. S S. Kuswah, Effect of Coconut Fiber and Fly Ash on Concrete, International Journal of Science Technology & Engineering 2 (2015) 127-133.http://www.ijste. org/articles/IJSTEV2I3038.pdf.

[12] Amit Rai, Dr. Y.P. Joshi, Applications and properties of fiber reinforced concrete, International Journal of Engineering Research and Applications 4 (2014) 123-131. https://www.academia.edu/ 7676360/ Applications_and_Properties_of_F.