REVISTA MATÉRIA V.28 N.3
ISSN 1517-7076 articles e20230190, 2023

Influence of presaturated coconut fibre ash pellets in concrete

Gopi Rajamanickam[1], Saravanakumar Ramasamy[2], Elango Krishnan Soundararajan[2], Kathiresan Karuppanan[3], Chandrasekar Arumugam[4]

[1]Marri Laxman Reddy Institute of Technology and Management, Department of Civil Engineering. Hyderabad,Telangana, India.

[2]KPR Institute of Engineering and Technology, Department of Civil Engineering. Coimbatore, Tamilnadu, India.

[3]Dire-Dawa University, School of Civil Engineering and Architecture. Dire Dawa, Ethiopia.

[4]PSNA College of Engineering and Technology, Department of Civil Engineering. Dindigul, Tamilnadu, India.

e-mail: gopierode4@gmail.com, saravanakumartg@gmail.com, kselango04@gmail.com, kathiresan.Karuppanan@ddu.edu.et, acscvl@gmail.com

ABSTRACT

River sand is becoming increasingly scarce. As a result, an alternative material is required to replace river sand in order to save river sand. In the construction of quality concrete, artificial aggregate is now frequently employed as a substitute for river sand. Coconut fibre ash (CFA) aggregate obtained from Coconut fibre is prevalent in India. Partially replacing river sand (fine aggregate) with presaturated CFA aggregate for self curing purpose is presented in the paper. Fine aggregates were replaced by CFA aggregate by 5%, 10%, 15%, 20% and 25% by volume. The workability and strength characteristics of the concrete are studied. Internal curing is the solution to today's water scarcity's insufficient curing. During compared to other mixtures, test results show that the concrete mix with 20% CFA aggregate produced better results when self curing.

Keywords: CFA aggregate; Self curing; Strength properties.

1. INTRODUCTION

The common names, scientific names, and plant families for coconut fibres are coir, cocos nucifera, and areca sativa, respectively [1]. Recently, researchers are investigating the utilization of agricultural waste into useful building products and to make sustainability [2]. Coir waste is a by-product of the process of extracting coir fibre from coconut shell. This coir trash was disposed of through burning. This burning resulted in a number of undesirable environmental issues [3]. So far, mostly industrial wastes, by products and solid wastes have been used in concrete. Many researches are carried out in the field of agricultural waste and also utilizing the agricultural waste ash in concrete and other building elements. Coconut fibre is the major agricultural wastes in India [4]. CFA contains composition of the compound Silica SiO_2 content of 61.74%. CFA composition confirms that the possible to work together along with fly ash as supplementary cementitious materials. It will reduce the CO_2 discharge in the cement production plants [5]. According to International Year For Natural Fibres 2009 farming the tree are approximately 12 million which create 5,00,000 tonnes of coir annually [6]. Nearly 50% of the coir's produced are exportation in the structure of unprocessed fibre only. The coconut fibres benefits include provide outstanding temperature and sound insulation material, unaffected by dampness, flame-retardant, hard and durable, flexible, return to original shape even after many use [7]. CFA is one of the natural fibres plentifully obtainable in tropical areas [8]. The major advantages of natural fibres are eco friendly materials. It is a substitution material for glass fibre in provisions of cost and structural characteristics. Coconut fibres majorly two types. In matured coconuts brown fibres extracted and in tender coconuts white fibres extracted. Brown fibres are commonly used because it is strong and thick compared to white fibres and having more abrasion resistance [9]. More than 93 countries in the world coconut are grown. India cultivates 1.78 million hectares of coconut, making it the world's third largest producer. The construction materials made with coconut fibres, improves the strength, sustainability and environmentally friendly in construction [10].

As long as the appropriate replacement percentage is followed, coconut fibre ash can replace fine or coarse material when making traditional concrete. Overall, using coconut fibre ash as fine aggregate can help produce concrete more affordably while also reducing trash disposal [11]. To create a less expensive structural

Corresponding Author: Gopi Rajamanickam Received on 29/06/2023 Accepted on 24/07/2023

DOI: https://doi.org/10.1590/1517-7076-RMAT-2023-0190

lightweight concrete using coconut shell ash as a partial replacement for cement, the optimal compressive strength value indicated in the research was applied. Partially replacement cement by CFA with a water cement ratio of 0.48 is appropriate for the construction of light weight constructions like flooring, lintels, and low cost housing projects. Additionally, due to the low cost and abundant availability of agricultural waste, utilising coconut shell as aggregate in concrete can lower the cost of construction materials [12].

A higher percentage of coconut fibre ash alone or even integrated with fly ash cannot be used for construction due to the increase in coconut fibre ash and fly ash of more than 20% failing to generate a good compressive strength [13]. With an increase in the quantity of coconut fibre ash, the compressive strength gradually decreases. With curing and ageing, the strength of the concrete improved. With an increase in coconut fibre ash percentage, the slump value falls. This shows that when the CFA content rose, the concrete became stiffer and less malleable [14]. By reducing the cement content while maintaining appropriate levels of compressive strength, tensile strength, and modulus of elasticity, CFA can be utilised to considerably reduce the price of concrete [15]. Additionally, it has been noted that adding a small quantity of CFA to seawater concrete increases its strength. The strength of the concrete becomes comparable to regular water-based concrete when coconut fibre ash is added [16].

To achieve essential mechanical and durability parameters of concrete curing is necessary at right and sufficient time. Curing is the practice of preserving sufficient wetness in concrete during hydration of cement. In order to improve the strength, long-term durability, water impermeability, volume stability, and freezing and thawing resistance of hardened concrete; it must be properly cured in a timely manner [17]. There are different methods of curing process. Self-curing or internal curing is done to make concrete more capable of retaining water by reducing water dispersion from within the concrete. Self-curing is a technique used to introduce more wetness to concrete in order to increase cement hydration and decrease self-desiccation [18].

Concrete that contains CFA as a partial replacement for cement sets more gradually and absorbs less water. With increasing percentages of CFA replacement in concrete, concrete strengths decline with increasing curing age. CFA use will lower the amount of cement used in light weight concrete, lowering the cost of producing concrete as a result. By using CFA, the environmental problems caused by the disposal of coconut fibre wastes will be reduced. As the percentage of CFA content rises, more water is needed in the mixture to achieve a paste of a standard consistency since CFA is lighter than OPC and takes up more space for the same mass of OPC [19]. In this paper the effect of presaturated CFA aggregate as a replacement of fine aggregate in concrete is studied.

2. MATERIALS AND METHODS

In this experimental work, Grade 53 OPC cement according to IS: 12269 [20] were employed. The Characteristics of cement are presented in Table 1. Physical characteristics of the river sand and coarse aggregate (20 mm size) were investigated and the outcomes are presented in Table 2. CFA aggregate pellets are made in a concrete mixer with a 20:80 (cement: coconut fibre ash) ratio, cured for 7 days, and left to dry. CFA aggregates are presaturated (saturated surface dry condition) for 24 hrs before being used in concrete for self curing purposes.

Table 1: Characteristics of Cement.

S.NO	CHARACTERISTICS	RESULT
1.	Setting time (initial)	35 min
2.	Setting time (final)	420 min
3.	Standard Consistency	32%
4.	Specific gravity	3.18
5.	Fineness (by sieving)	1%

Table 2: Characteristics of aggregates.

S.NO	CHARACTERISTICS	FINE AGGREGATE	COARSE AGGREGATE
1.	Fineness modulus	2.55 (Zone II)	6.28
2.	Specific gravity	2.72	2.81
3.	Bulk density	1580 kg/m^3	1579 kg/m^3

2.1. Preparation of CFA aggregates

Coconut fibres are gathered from a nearby farm area. A significant amount of coconut fibres end up as garbage in the environment. The appropriate use of this material in the construction sector will be a critical step toward cost-cutting and environmentally responsible building. Proportion of 80% ash and 20% cement are used to make coconut fibre ash pellets. Cement and CFA were mixed thoroughly in a dry state in a concrete mixer. Then the water was added to the dry mix and thoroughly mixed in the drum with 35° to 55° angle of inclination, until the process of formation of CFA aggregates was completed. The CFA aggregates having different sizes were taken out from the mixer machine and allowed to dry for a day. The aggregates were packed in gunny bags and immersed in curing tank for 7 days. After 7 days, the CFA aggregates was taken out from gunny bags and dried completely. Then aggregates are subjected to sieving by using appropriate sieves. The aggregates having size in the range of 1.18 mm to 4.75 mm are considered as fine aggregate.

2.2. Properties of coconut fibre ash aggregates

Before making the concrete for self-curing purposes, the CFA pellets were presaturated for 24 hours (Figures 1 and 2). Table 3 and Table 4 shows the physical and chemical features of CFA aggregate. Silica is present in greater amounts in coconut fibre ash, according to its chemical components. Alkali oxides, iron oxides, and magnesium oxides were also identified in trace amounts. The study's water source was the potable water available on campus.

Figure 1: Coconut fibre ash.

Figure 2: Coconut fibre ash pellets.

Table 3: Physical characteristics of CFA aggregates.

S.NO	CHARACTERISTICS	RESULT
1.	Bulk density	830.56 kg/m^3
2.	Water absorption	13%
3.	Specific gravity	1.78

Table 4: Chemical characteristics of CFA.

S.NO	PARAMETERS	RESULT
1.	Loss of ignition	3.58%
2.	Magnesium oxide (MgO)	6.51%
3.	Iron oxide (Fe_2O_3)	0.95%
4.	Sand & silica	61.74%
5.	Calcium oxide (CaO)	11.50%
6.	Aluminium oxide (Al_2O_3)	12.44%

3. METHODOLOGY

The concrete mixes were prepared by substituting CFA aggregate pellets for river sand by volume ranging from 0% to 25% by volume at a rate of 5%. Control mix (CM) was defined as a mix that did not contain any CFA aggregate pellets. The replacement percentage is specified by the numbers in concrete mix id. The workability of fresh concrete was assessed using the slump, vee-bee consistometer and compaction factor tests. To compute the hardened concrete parameters, 36 nos. of 150 mm cubes for compressive strength, 36 nos. of 150 mm x 300 mm cylinders for split tensile strength and 36 nos. of 500 mm x 100 mm x 100 mm beams for flexural strength tests are casted. For each mix and each category of test an average of three test results is taken. In order to reduce the moisture loss from the CFA specimens after they were cast, they were remoulded 24 hours later and covered with plastic sheets. The water used for self curing was not a part of the mixing water used in the manufacturing of concrete. The control mix (CM) specimens were remoulded and cured in water for 7 and 28 days. The compressive strength (Figure 3), split tensile strength (Figure 4) and flexural strength (Figure 5) characteristics of the test samples were identified according to IS: 516 [21] recommendations. For each combination, three samples were examined for various qualities of hardened concrete. The test findings obtained were used to determine the significant substitution level of CFA pellets.

3.1. Concrete mix proportions

In this experimental work, M25 concrete grade was carried out in compliance with IS: 10262 [22]. Totally six mixes were prepared including control mix. River sand was replaced by presaturated CFA by volume basis. The proportions of various ingredients for each concrete mix are presented in Table 5.

Figure 3: Compression strength test.

Figure 4: Tensile strength test.

Figure 5: Flexural strength test.

Table 5: Concrete mix proportion for various mixes.

MIX ID COMPOSITION	CM	CFA_5	CFA_{10}	CFA_{15}	CFA_{20}	CFA_{25}
Cement [kg/m^3]	350					
CFA aggregate [kg/m^3]	–	17.25	34.46	51.70	68.93	86.17
River sand [kg/m^3]	647	615.85	582.37	550.06	517.75	485.43
Coarse aggregate [kg/m^3]	1335.73					
Water [kg/m^3]	140					
Super plasticizer (% by weight of powder content)	1					
Water-Cement ratio	0.40					

3.2. Workability characteristics

The workability properties for CFA aggregate are shown in Table 6. All the concrete mixes are attained workability characteristics within the acceptable limits.

The workability of concrete demonstrates that the workability reduced gradually making the concrete adequately workable.

3.3. Experiments on hardened concrete

The mechanical characteristics of all the proportions are displayed in Table 7.

Table 6: Workability characteristics.

S.NO	WORKABILITY TEST	WORKABILITY TEST RESULTS					
		CM	CFA_5	CFA_{10}	CFA_{15}	CFA_{20}	CFA_{25}
1.	Slump (mm)	19	20	21	22.5	24	25
2.	Vee-bee (sec)	4	4	5	6	7	8
3.	Compaction factor	0.97	0.96	0.95	0.93	0.92	0.90

Table 7: Hardened concrete characteristics.

S.NO	MIX ID	COMPRESSIVE STRENGTH (MPa)		SPILT TENSILE STRENGTH (MPa)		MODULUS OF RUPTURE (MPa)	
DAYS		7	28	7	28	7	28
1.	CM	26.87	31.73	2.95	3.46	4.60	5.18
2.	CFA_5	29.50	32.23	2.97	3.50	4.93	5.22
3.	CFA_{10}	30.48	34.86	3.05	3.60	4.96	5.28
4.	CFA_{15}	30.73	36.16	3.08	3.62	4.98	5.88
5.	CFA_{20}	34.52	38.78	3.31	3.72	5.17	6.73
6.	CFA_{25}	32.22	33.86	3.09	3.65	5.08	6.20

4. RESULTS AND DISCUSSION

The mechanical characteristics of the concrete are given in Figure 6, Figure 7 and Figure 8.

Control mix has a compressive strength of 31.73 MPa under external curing conditions, while CFA20 has a compressive strength of 38.78 MPa under self-curing conditions. This shows that increasing CFA to 20% enhances strength for the first 28 days, but then decreases. It is evident that improved interfacial zone and improved hydration are the causes of CFA concrete's better compressive strength. The CM mix spilt tensile strength was 3.46 MPa under external curing conditions, and 3.72 MPa under self-curing conditions. This illustrates that increasing CFA by 20% first increases strength but subsequently decreases after 28 days. The modulus of rupture of the CM mix was 5.18 MPa under external curing conditions and 6.73 MPa for CFA20 under self curing conditions. This shows that increasing CFA by 20% increases strength for the first 28 days, but afterwards strength decreases. The high silica and alumina content of the CFA is responsible for the improvement in strength since they help to improve the hydration process [23]. Due to its enhanced hydration during self-curing, cement paste can be made denser and harder and encircled by CFA aggregate that has been presaturated [24]. The CFA aggregate that has been presaturated has the necessary moisture content to support the hydration process. The CFA aggregate ensures that the concrete hydrates completely by allowing moisture content to migrate from the interior to the exterior. The pozzolanic components of CFA can transform calcium hydroxide from cement paste into calcium silicate hydrate (C-S-H) as a strength product. Additionally, the capillary voids are

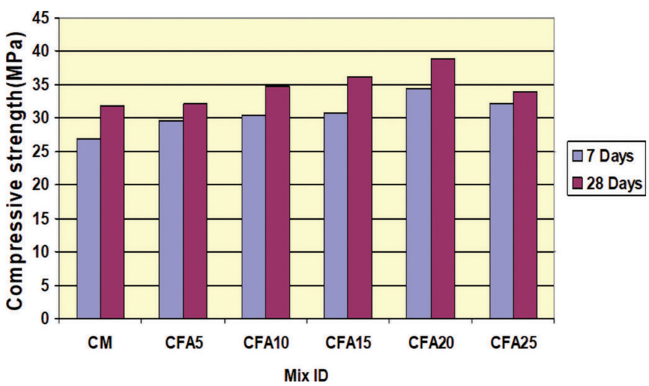

Figure 6: Compressive strength.

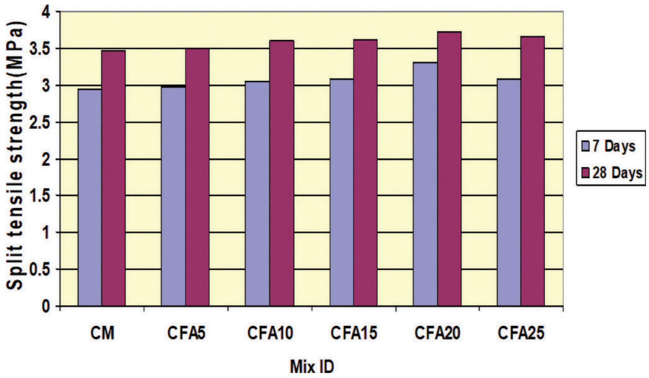

Figure 7: Split tensile strength.

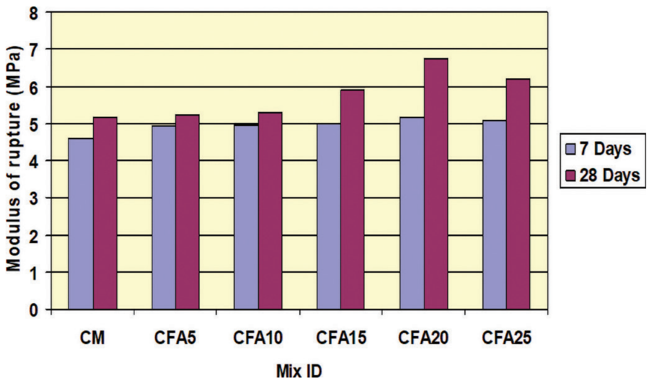

Figure 8: Flexural strength.

either eliminated or reduced in size. In turn, this enhances the strength and durability of the hydrated paste as well as the cement-concrete's other qualities [4].

5. CONCLUSION

The fresh concrete workability parameters were satisfied by all CFA aggregate and control mix combinations. Under self-curing, the 20% CFA-substituted mixture outperformed the control mixture in terms of compressive strength (22.21%), split tensile strength (7.51%), and modulus of rupture (29.92%). Self curing structural concrete with presaturated CFA aggregate has been offered as a viable option. Self curing is the most effective method for preventing early age shrinkage, as well as insufficient curing in today's water-scarce world. Self-curing concrete may have a higher strength than concrete that has been cured under regular conditions. Concrete strength development due to CFA's pozzolanic action, which contributes to a better hydration process and thus increased strength. Due to the absorbed water, self-curing cement paste surrounded by presaturated CFA aggregate becomes denser and harder.

6. BIBLIOGRAPHY

[1] ALI, M., "Coconut fibre: a versatile material and its applications in engineering", *Journal of Civil engineering and construction Technology*, v. 2, n. 9, pp. 189–197, 2011.

[2] ALI, M., NOLOT, B., CHOUW, N. "Behaviour of coconut fibre and rope reinforced concrete members with debonding length", In: *Proceedings of the Ninth Pacific Conference on Earthquake Engineering*. New Zealand, 2011.

[3] PARAMANANDHAM, J., RONALD ROSS, P., "Lignin and cellulose content in coir waste on subject to sequential washing.", *Journal of Chemistry and Chemical Research (India)*, v. 1, n. 1, pp. 10–13, 2015.

[4] BAYUAJI, R., KURNIAWAN, R.W., YASIN, A.K., *et al*., "The effect of fly ash and coconut fibre ash as cement replacement materials on cement paste strength", *Materials Science and Engineering*, v. 128, n. 1, pp. 12014, 2014.

[5] AGRAWAL, R.A., DHASE, S.S., AGRAWAL, K.S., "Coconut fiber in concrete to enhance its strength and making lightweight concrete", *International Journal of Engineering Research and Development*, v. 9, n. 8, pp. 64–67, 2014.

[6] ALI, M., LIU, A., SOU, H., *et al*., "Mechanical and dynamic properties of coconut fibre reinforced concrete", *Construction & Building Materials*, v. 30, pp. 814–825, 2012. doi: http://dx.doi.org/10.1016/j.conbuildmat.2011.12.068.

[7] BRAHIM, S.B., CHEIKH, R.B., "Influence of fibre orientation and volume fraction on the tensile properties of unidirectional alfa-polyester", *Composites Science and Technology*, v. 67, n. 1, pp. 140–147, 2007. doi: http://dx.doi.org/10.1016/j.compscitech.2005.10.006.

[8] BRAHMAKUMAR, M., PAVITHRAN, C., PILLAI, R.M., "Coconut fibre reinforced polyethylene composites: effect of natural waxy surface layer of the fibre on fibre/matrix interfacial bonding and strength of composites", *Composites Science and Technology*, v. 65, n. 3–4, pp. 563–569, 2005. doi: http://dx.doi.org/10.1016/j.compscitech.2004.09.020.

[9] EALIAS, A.M., RAJEENA, A.P., SIVADUTT, S., *et al*., "Improvement of strength of concrete with partial replacement of course aggregate with coconut shell and coir fibres", *Journal of Mechanical and Civil Engineering*, v. 11, n. 3, pp. 16–24, 2014. doi: http://dx.doi.org/10.9790/1684-11321624.

[10] YERRAMALA, A., RAMACHANDRUDU, C., "Properties of concrete with coconut shells as aggregate replacement", *International Journal of Engineering Inventions*, v. 1, n. 6, pp. 21–31, 2012.

[11] FAHEEM, Z., UMAR, K., "Utilization of coconut fiber ash as sand aggregate replacement for pavement block", *Journal of Advanced Research in Engineering Knowledge*, v. 10, n. 1, pp. 1–9, 2020.

[12] KUMAR, L., PANDEY, K.K., KHAN, S., "Use of coconut shell ash as aggregates.", *International Journal of Research in Engineering and Social Sciences*, v. 7, n. 2, pp. 15–19, 2017.

[13] WUNGKO, P.B., BINDUMATHI, K., "Examining concrete properties using coconut fiber ash and fly ash as partial replacement for cement", *International Journal of Engineering Trends and Technology*, v. 46, n. 5, pp. 240–245, 2017. doi: http://dx.doi.org/10.14445/22315381/IJETT-V46P241.

[14] SANJAY, S., RAJEEV, C., "Effect of coconut fibre ash on strength properties of concrete", *International Journal of Engineering Research and Applications*, v. 5, n. 4, pp. 33–35, 2015.

[15] WAQAR, A., BHEEL, N., ALMUJIBAH, H.R., *et al*., "Effect of Coir Fibre Ash (CFA) on the strengths, modulus of elasticity and embodied carbon of concrete using response surface methodology (RSM) and optimization", *Results in Engineering*, v. 17, pp. 100883, 2023. doi: http://dx.doi.org/10.1016/j.rineng.2023.100883.

[16] KUMAR, G.R., KESAVAN, V., "Study of structural properties evaluation on coconut fiber ash mixed concrete", *Materials Today: Proceedings*, v. 22, pp. 811–816, 2020. doi: http://dx.doi.org/10.1016/j.matpr.2019.10.158.

[17] LU, L., YANG, W., HE, Y., *et al*., "Internal curing using water-releasing material for high strength micro-expansive concrete", *Journal of Wuhan University of Technology-Mater.*, v. 24, n. 3, pp. 510–513, 2009. doi: http://dx.doi.org/10.1007/s11595-009-3510-5.

[18] LURA, P., JENSEN, O.M., IGARASHI, S.I., "Experimental observation of internal water curing of concrete.", *Materials and Structures*, v. 40, n. 2, pp. 211–220, 2007. doi: http://dx.doi.org/10.1617/s11527-006-9132-x.

[19] ARIMANWA, M.C., ANYADIEGWU, P.C., OGBONNA, N.P., "The potential use of coconut fibre ash in concrete", *The International Journal of Engineering and Science*, v. 9, n. 1, pp. 68–75, 2020.

[20] BUREAU OF INDIAN STANDARDS, *IS: 12269-2013, Ordinary Portland Cement 53 Grade – Specification*, New Delhi, India, Bureau of Indian Standards, 2013.

[21] BUREAU OF INDIAN STANDARDS, *IS: 516-2018, Methods of test for strength of concrete*, New Delhi, India, Bureau of Indian Standards, 2018.

[22] BUREAU OF INDIAN STANDARDS, *IS: 10262-2009, Concrete mix proportioning-Guidelines*, New Delhi, India, Bureau of Indian Standards, 2009.

[23] RAJAMANICKAM, G., VAIYAPURI, R., "Self compacting self curing concrete with lightweight aggregates", *Gradevinar*, v. 68, n. 4, pp. 279–285, 2016.

[24] GOPI, R., REVATHI, V., KANAGARAJ, D., "Light expanded clay aggregate and fly ash aggregate as self-curing agents in self-compacting concrete", *Asian Journal of Civil Engineering*, v. 16, n. 7, pp. 1025–1035, 2015.