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Strength Performance Of Coir Fiber Concrete With Wollastonite As Partial Cementitious Material To Control Global Warming

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ABSTRACT

In construction of structures, adding cementitious and supplementary materials to cement concrete has grown to reduce costs, save energy, and protect the environment. Wollastonite is a natural mineral ($CaSiO_3$), When it hydrates calcium Silicate – calcium-silicate-hydrate compound will be formed and it strengthens cement. The high availability and low demand of Wollastonite has subsequently increased the chances of implementation in cement concrete technology to reduce the carbon foot print. Since the availability of coir fiber in nature is abundant and will become more economical to use as reinforcement in concrete due to its crack reduction capacity. This work is focused on compressive and tensile strength performances of coir fiber concrete under the influence of wollastonite as partial cementitious material. The addition of coir fibres is kept constant as 0.6% by weight of cementitious material. Wollastonite as cementitious material replaced the cement in varying proportions of 0%, 10%, 12.5%, 15% and 17.5% by mass of cement. Both the strengths of coir Fiber concrete were studied under the influence of wollastonite. 10% wollastonite by mass of cement influences for better strength in coir fiber concrete.

Keywords: *Fiber reinforced concrete, Coir Fiber, Wollastonite, compressive strength, Split tensile strength*

INTRODUCTION

To control global warming, an alternative supplementary cementitious material is very much required in concrete preparation by reducing the cement content in it. Since cement is the second largest usage material after water, it emits 0.8 ton of CO_2 by utilising 1.5 ton of raw materials and has a massive carbon foot print (Omri Imen Yamina et al., 2022). Supplementary cementitious materials such as metakaolin, fly ash, silica fume, and wollastonite are to increase the durability and strength properties of concrete. Among these materials, wollastonite has certain advantages due to its lower cost, workability, ability of enhancing mechanical properties, and with low carbon content. Hence by using wollastonite as partial cementitious material in concrete production will aid in reducing the carbon foot print and thereby it will add a value to control global warming.

From the studies of Renu et al. (2007), the addition of wollastonite improved the durability of concrete due to formation of discontinuous pores and which lead to low permeability. Since the wollastonite lowers the workability for its improvement addition of super plasticizer is necessary. Concrete durability is also studied by Pawan et al. (2015) when the wollastonite is replaced the cement by 0 to 25%. Strength and durability of concrete are improved when wollastonite replaced the cement with 10 to 15% by weight of cement. In another study, Kandula mohankrishna & Gopala Krishna (2016) with the same percentage range of wollastonite, the strength and durability of concrete are improved. In which 10% replacement showed best results for strength of concrete. But strength is reduced if the wollastonite replaced the cement by more than 20% by weight of cement. Less than or equal to 15% replacement by wollastonite decreases the permeability and makes the denser concrete. Moreover, wollastonite reduces shrinkage strains and increases the cracking resistance. Since wollastonite reduces the concrete workability, superplasticizer (Fosroc SP340) is used to enhance it. Strengths of wollastonite added concrete beams and cubes were studied by Borkar et al. (2019). The specimens are prepared with 0%, 10%, 15% and 20% replacement of cement by wollastonite. It was found that when the wollastonite replaced the cement by 15% which resulted in increased flexural and compressive strengths of concrete. Ziming He et al. (2020) reviewed the wollastonite microfibers effect in partially replacing the cement on the progress and mechanism of cementitious composite properties. In this review, some researchers' observations are highlighted that the microfibers of wollastonite influences the tensile and compressive strengths of concrete. Nishant A Nair and V.

Sairam (2021) reviewed the technical papers published from 1992 to 2020 on influence of wollastonite by either partially replacing the sand or cement. It increases the durability and bending strength of concrete and reduces water absorption and drying- shrinkage. Workability and strength are maximum when the wollastonite replaced the cement by 30% in recycled waste ceramic aggregated (RWCA) based concrete. In fire accidents of buildings, the microstructure of concrete changes and leading to deterioration of concrete. Since wollastonite melting point is 1540 ^{0}C, it's coefficient of thermal expansion is low. Yi-sheng wang et al.(2025) effectively optimized the durability of limestone calcined cement with wollastonite by utilizing its high temperature stability. Hence from the literature it was observed that whenever the wollastonite replaced the cement from 10% to 15%, it improves durability, tensile and compressive strengths and whenever wollastonite replaces the cement by more than 20%, it will reduce the concrete compressive strength.

In concreting process, excessive use of cement lead to development of shrinkage and micro cracks in concrete and causes elastic deformation. These cracks will be arrested if the fibers are already reinforced in concrete. Fibre reinforced composite concrete significantly increase the tensile, compressive, impact and flexural strength. To produce structural lightweight concrete, Noor et al. (2012) studied the influence of coconut fiber in it. The length of fibers used was 15 mm to 35 mm and diameter was 0.17 mm to 0.24 mm. Volume percentages of coconut fiber used in this work were 1, 3, 5 and 7 by total volume. Concrete strength is decreased with increase in fiber percentage in concrete mix. It was also observed that there is a decrease in crack width and development of crack numbers. Darsana. P et al. (2015) developed light weight eco-friendly coir fiber cement composite for roofing tiles. Ductility and breaking load were optimized with 10% by volume of replacing the cement with coir fibre. From the cost analysis made it was concluded that composite tile with coir fiber is cheaper to cement concrete tile. Habibunnisa et al (2020) investigated the presence coir fiber role in concrete. In total weight of concrete, if coconut fiber percentage is 0.6 and 1.2, the compression strength was good at 0.4 water cement ratio. But with mesh fibers, weak transition zone around the fibers will be formed and lowering the strength. Jawad Ahmad et al. (2022) reviewed the technical papers on durability and mechanical performance of concrete composite coconut fibres. For better durability and strengths, 2 to 3% by volume of cement is the optimum dose of coconut fiber identified by many researchers. Antony & sujatha (2023) investigated the strength performance of concrete composite with coconut fibers. In this work, coconut fiber mass with mass of cement were chosen as 0.5%, 1%, 1.5% and 2%. The lenth of fibers were chosen as 25, 50 and 75 mm. From the strenthss obtained, the optimum content of fiber was 0.5% with 75 mm long fibers.

Priya s. Nair et.al. (2025) investigated the self- healing performance, strength properties and durability of 10% wollastonite and 10% bio consortium pineapple leaf fiber (PALF) reinforced concrete. In this study, at 28 days, bending and compressive strengths increased by 16% and 26.7% respectively and 90 days strengths are 14% and 25.9% respectively. Findings from this study offers a sustainable solution if the structures exposed to chemical or environmental deterioration. Under the influence of wollastonite, the strength performance of Coir fiber concrete had not been investigated much in detail.

OBJECTIVE AND SCOPE

Strength performance of coir fiber concrete composite under the influence of wollastonite as partial cementitious material are to be investigated.

To meet the objective, M30 grade concrete is used with addition of coir fibres and wollastinite as partial cementitious material by replacing the cement. Coir fiber concrete composite cubes and cylinders of M30 grade were prepared with 0%, 10%, 12.5%, 15% & 17.5% by weight of cement of wollastonite with addition of constant 0.6% by weight of cement of coir fibers and cured in water for 7, 14 and 28 days. For the water cured specimens, compression and split tensile tests were conducted.

METHODOLOGY

The sequence of the methodology is a self-explanatory from the Figure 1.

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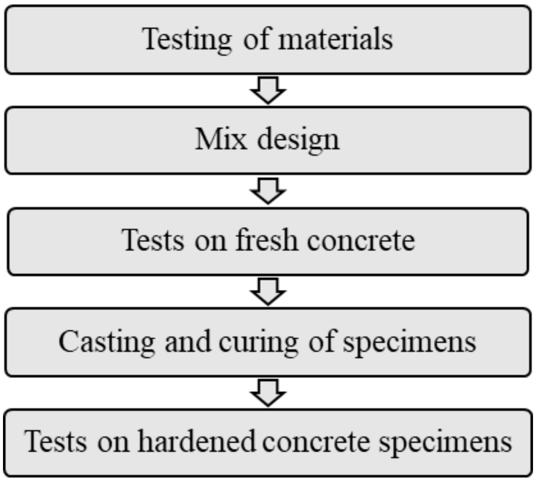

Figure 1: Methodology chart

Material testing
Cement, wollastonite, FA, CA, coir fiber and superplasticizer are the materials utilized in this work.

Tests on cement
Various tests shown in Table 1 were conducted on 53 grade OPC and obtained values also shown in the table with IS standard values.

Table 1: Tests on 53 grade OPC

Test Name	Apparatus	Obtained values	Standard values	IS code
Specific gravity	Le Chatelier flask	3.16	3.15	IS 4031 (Part II) -1988
Standard Consistency	Vicat apparatus	31%	26% to 33%	IS 4031 (Part4) -1988
Initial setting time	Vicat apparatus	32 minutes	≥ 30 minutes	IS12269:2013
Final setting time	Vicat apparatus	600 minutes	600 minutes	IS12269:2013
Soundness	Le chatlier's apparatus	10 mm	≤ 10 mm	IS12269:2013

Specific gravity of wollastonite
Wollastonite is used in its powdered form for this study for partially replacing the cement and is shown in the Figure 2. Specific gravity of wollastonite is determined as 3.06 using Le Chatlier's flask.

Figure 2: Wollastonite

Tests on FA (M-sand)
The specific gravity of FA was 2.65 and it is within the range of 2.3 to 2.7 as per IS 2386 (Part 3) -1963 (Reaffirmed in 2021). The obtained fineness modulus of fine aggregate using sieve analysis was 2.486 and it is conforming to zone 3 of Table 9 of IS383:2016.

Preparation of coir fibres
When coir fibres are added to fresh concrete, it absorbs some amount of water. This reduces the fresh concrete workability. . In order to overcome this limitation, the coir fibres are soaked in oil for 10 minutes and then

sundried for 24 hours. The oil coats the surface of the coir fibres and thereby reduces the water absorption. The fiber content is chosen as 0.6% by weight of cementitious material to prepare the mix.

Figure 3: Coir fibre (A) soaked in oil (B) dried under the sun

Tests on 20 mm size CA

The specific gravity of CA was obtained as 2.9 and it is within the range of 2.5 to 3.0 as per IS 2386 (Part3) – 1963 (Reaffirmed in 2021). The obtained fineness modulus of coarse aggregate using sieve analysis was 7.0 which is within the range of 6.0 to 8.5 as per IS 383:2016.

superplasticizer (Forsoc conplast SP430) content

Since the wollastinite addition reduces the workability in concrete, the dosage of superplasticizer varies for different proportions of wollastonite as shown in Table 2. Wollastonite percentages indiacted in table are by mass of cement.

Table 2: Optimum dosage of admixture SP430 for each mix added by weight of cementitious material

Type of mix	Abbreviation	SP430 (%)
CC	Conventional Concrete	0.5
CFRC0	Coir Fiber Reinforced Concrete with 0% wollastonite	0.5
CFRC10	Coir Fiber Reinforced Concrete with 10% wollastonite	0.5
CFRC12.5	Coir Fiber Reinforced Concrete with 12.5% wollastonite	0.6
CFRC15	Coir Fiber Reinforced Concrete with 15% wollastonite	0.6
CFRC17.5	Coir Fiber Reinforced Concrete with 17.5% wollastonite	0.7

Mix Design

M30 grade concrete mix is designed according to the guidelines of IS 10262:2019 with 0%, 10%, 12.5%, 15% and 17.5% wollastonite by weight of cement. The addition of coir fibres is 0.6% by weight of cementitious material and is kept constant for all proportions of wollastonite. The mix proportions of ingredients were calculated and is tabulated as shown in Table 3. Mix proportion is obtained as 1: 1.43: 3.04. W/C is 0.4.

Table 3 Mix proportion quantities in Kg/m^3

Materials	CC	CFRC0	CFRC10	CFRC12.5	CFRC15	CFRC17.5
Cement	410	410	369	358.75	348.5	338.25
Wollastonite	0	0	41	51.25	61.5	71.75
FA	586.756	586.756	586.829	586.847	586.865	586.884
Coir fibre	2.46	2.46	2.46	2.46	2.46	2.46
CA	1246.448	1246.448	1246.604	1246.643	1246.682	1246.721
Admixture	2.05	2.05	2.05	2.46	2.46	2.87
Water	164	164	164	164	164	164

Test on fresh concrete

The slump value was found as 125 mm and it indicates high workability as per IS 456: 2000.

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Casting and curing of specimens

- Weigh the desired quantity of cement, wollastonite, M-sand, coir fibers and coarse aggregates to prepare the cubes and cylinders using moulds.
- First mix the cement and wollastonite thoroughly. Once they are mixed, add M-sand to the mixture. Next sundried coir fibres (approximately 5 cm in length) are added to the mixture and thoroughly mix until the fibres are uniformly distributed throughout the batch. Next add CA to the above mixture until it is distributed uniformly in it.
- With the help of measuring jar add water in parts. Superplasticizer should not be added separately to the batch. The superplasticizer should be mixed with a small quantity of water (approximately with 20% of total water quantity) and should be added only after the remaining 80% of the water is added completely. The homogeneous mixture of fresh concrete is casted in moulds as per standard procedure and left for 24 hours as shown in Figure 4.

Figure 4: Concrete cubes and cylinders

- As shown in Figure 5, demolded cubes and cylinders are marked for future identification and submerged in water for 7, 14, 28 days. Next remove the specimens from water for testing.

Figure 5: Curing of specimens

Tests on hardened concrete specimens:

To determine the compressive strength, concrete composite cubes are kept under compression in compression testing machine. Similarly to find split tensile strength, concrete composite cylinders are kept under compression in compression testing machine as shown in Figure 6.

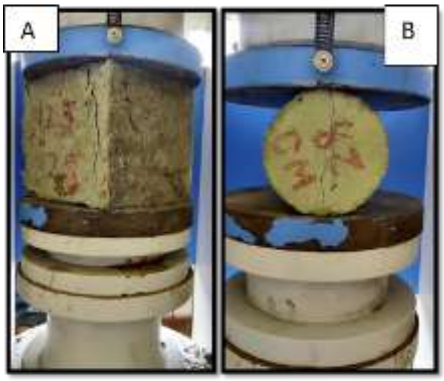

Figure 6: Testing for 28 day strength of (A) CFRC12.5 cube and (B) CFRC0 cylinder

RESULTS AND DISCUSSION

Compressive strength:

Compressive strength values of the concrete for the six sets of cubes prepared with variation of wollastonite percentages and constant addition of coir fibres by 0.6% of the weight of cementitious material after cured them for 7, 14 and 28 days are shown in Figure 7. First set of cubes were prepared without wollastonite and coir fibres. From the second set to the sixth set, the cubes were prepared with 0.6% constant coir fibre by weight of cementitious material and varying proportions of wollastonite by weight of cement as 0%, 10%, 12.5%, 15% & 17.5%.

As calculated earlier, the target strength of cube to be achieved is 38.25 MPa after 28 days curing. From the Figure 7, it is achieved as 39.96 MPa for the concrete cube prepared without adding coir fibres and wollastonite and it is more than the target value.

For CFRC cube specimens prepared with 10% wollastonite by weight of cement, in 7 days 25% of 28 days strength was achieved; and in 14 days 56% of 28 days strength was achieved which is depicted from the Figure 7. The strength attained is comparatively lesser but it does not affect the 28 days strength. The 28 days strength was 41.21 MPa and it is higher than the target value. This initial retardation of the strength attainment is due to the usage of superplasticizer, which retards the hardening of concrete but do not affect the 28 days strength value when cured accordingly.

12.5% replacement of cement by wollastonite in CFRC worked well in attaining the initial strength but did not give satisfactory results at 28 days as 10% wollastonite by weight of cement in CFRC.

After 28 days, highest strength of 41.21 MPa was achieved for the CFRC cubes prepared with 10% wollastonite by weight of cement and it is shown in Figure 7. This is about 3.2% higher value compared to the conventional concrete cubes.

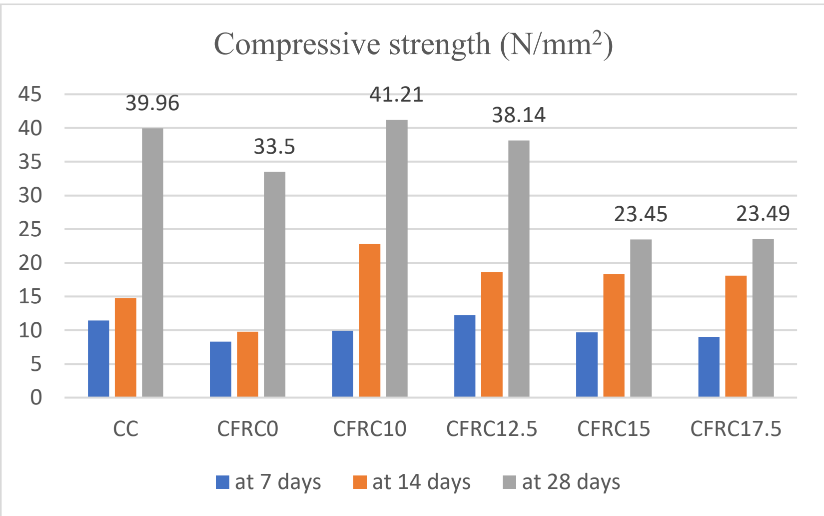

Figure 7 Compressive strengths at 7, 14 and 28 days cured various concrete cubes

Split tensile strength:

Split tensile strength of the cylinders are shown in Figure 8. Out of all cylinders, CFRC cylinders with 10% wollastonite by weight of cement shows good results and it is depicted from the Figure 8. This is about 3.2% higher strength compared to the conventional concrete cylinders.

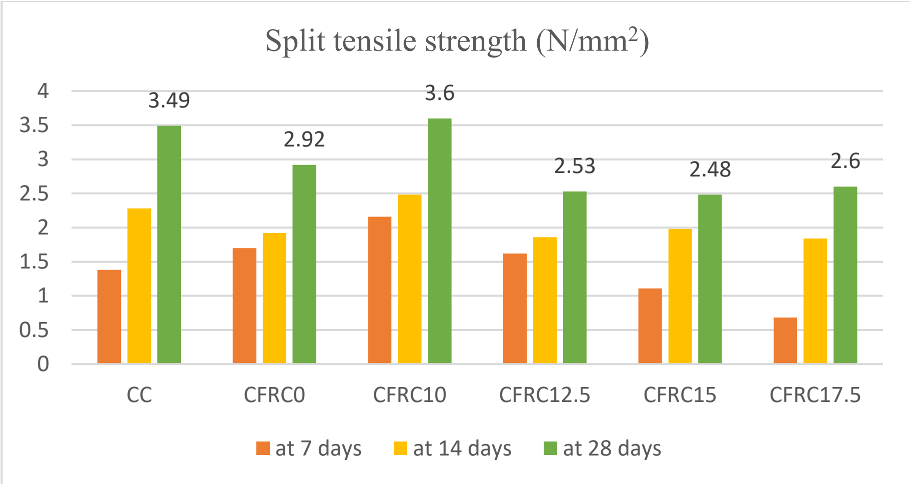

Figure 8: Tensile strength at 7, 14 and 28 days cured various concrete cylinders

CONCLUSIONS

Influence of wollastonite as partial cementitious material in coir fibre reinforced concrete composite was investigated experimentally by conducting compression and split tensile tests in this study. The conclusions were drawn as follows.

- 10% wollastonite by weight of cement has shown increase in both compressive and tensile strengths. Hence 10% replacement of cement with this cementations material will add a value to control global warming and save the environment.
- 12.5% wollastonite by weight of cement facilitates the initial strength of concrete compared to 10% wollastonite by weightof cement. Since the concrete workability reduces due to wollastonite, optimum usage of superplasticiser ranging from 0.5% - 0.7% by weight of cementitious material is used to increase the workability. The usage of superplasticiser retards the initial hardening of concrete but does not affect the 28th day strength.
- The reinforcement of Coir fiber in concrete (0.6% by weight of cementitious material) reduced the number of cracks and depth of cracks. Since coir fiber absorbs water required for workability and hydration, they are soaked in oil for 10 minutes and sun dried for 24 hours
- Though the specimen fail at its peak load, the reinforcement of coir fiber in concrete ensured that the corners and edges of the concrete did not wear off completely from the core specimen. Hence it can be used in earthquake prone zones
- Coir fiber usage reduced the net weight of the specimen. This leads to economical construction

REFERENCES

[1] Antony Varghese, Sujatha Unnikrishnan (2023). Mechanical strength of coconut fiber reinforced concrete. Materials today proceedings.
[2] Darsana. P, Ruby Abraham, Anu Joseph, Arakkal Jasheela, Binuraj.P.R & Jithin Sarma (2016). Development of coir-fibre cement composite roofing tiles, Proceedia Technology, 24, 169-178.
[3] Fosroc Conplast SP430, User guide from www.fosroc.com
[4] Habibunnisa Syed, Ruben Nerella & Sri Rama Chand Madduru (2020). Role coconut coir fibre in concrete, Materials Today: Proceedings, 27(2), 1104-1110.
[5] IS 383:1970. Indian Standard Specification for Coarse and Fine Aggregates from Natural Sources for Concrete
[6] IS 383: 2016. Coarse and Fine Aggregates for concrete – specification

[7] IS 456: 2000. Indian standard plain and reinforced concrete- code of practice
[8] IS 9103: 1999. Indian Standard Concrete Admixtures – Specification
[9] IS 10262:2019. Concrete Mix proportioning – Guidelines
[10] IS 12269: 2013. Indian Standard Ordinary Portland Cement 53 Grade – Specification
[11] Jawad Ahmad, Ali Mazdi, Amin AI-Fakh, Ahmed Farouk Deifalla, Fadi Althoey, Mohammed Hechmi EI ouni, Mohammed A. EI Shorbagy (2022). Mechanical and Durability Performance of Coconut Fiber Reinforced Concrete: A State-of-the-Art Review. Materials, 15(10), 15103601.
[12] Kandula mohankrishna reddy, K.V.S. Gopala Krishna Sastry (2016), Strength properties of concrete using wollastonite-flyash and wollastonite-silica fume. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), 6(5), 1-12.
[13] M. Borkar, S Zade, B.Dongre, P. Sakharkar, (2019). To Study the Strength of Concrete by adding Wollastonite in it", IOSR journal of Engineering, 6, 20-29.
[14] Nishant A.Nair, V.sairam (2021). Research initiatives on the influence of wollastonite in cement-based construction material- A review. Journal of cleaner production, 283, 124665.
[15] Noor Md. Sadiqul Hassan, Habibur Rahman Sobuz, Md. Shiblee Sayed & Md. Saiful Islam (2012). The use of coconut fibre in the production of structural light weight concrete. Journal of applied sciences, 12(9), 831-839.
[16] Omri Imen Yamina, Rahmouni Zine El Abidine, Tebbal Nadia (2022). Review about the effect of chemical activation of industrials waste which is rich by SiO2 and CaO. Materials today: Proceedings, 49 (4), 997-999.
[17] Pawan Kalla, Aditya Rana, Yog Bahadur Chad, Anurag Misra, Laszlo Csetenyi (2015). Durability studies on concrete containing wollastonite, Journal of cleaner production, 87, 726-734.
[18] Priya S.Nair, Rizwan Ahmad Khan, Rajesh Gupta, Vinay Agrawal, Prakash Somani, Blessen Skariah Thomas (2025). Enhanced durability and strength of bio-wollastanite fiber- reinforced concrete using MICP technique. Construction and building materials, 479, 141533
[19] Renu Mathur, A.K.Misra, Pankah Goel (2007). Influence of Wollastonite on Mechanical Properties of Concrete, Journal of scientific & industrial research, 66, 1029-1034.
[20] Yi-Sheng Wang, Taewan Kim, Runsheng Lin, Xiao-Yang Wang (2025). Deterioration behaviour and microevolution of limestone – calcined Hwangtoh clay cement (LC3) with wollastonite after high-temperature exposure. Construction and Building Materials, 485, 141944.
[21] Ziming He, Aiquin Shen, Zhenghua Lyu, Yue Li, Hansong Wu, wenzhen Wang (2020). Effect of wollastonite microfibers as cement replacement on the properties of cementitious composites: a review. Construction and Building Materials, 261,119920.