Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

An Experimental Investigation on Acidic and Alkali Resistance of Ternary Blended Coir and Flax Concrete

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Natural fibres are added to M30 concrete to increase its strength and improve its resistance to cracking. M30 concrete is a type of high-strength concrete that is often used for the construction of buildings. Natural fibers such as coconut coir, flax, and sisal can be integrated into M30 concrete to enhance its durability and resistance. The inclusion of these fibres helps to reduce cracking and improve the overall structural integrity of the concrete when exposed to acidic and alkaline conditions. Present research focuses on hybridizing coir and flax with M30 concrete that has been tested for alkali resistance. A mixture of 3% coir and 1% flax samples were tested for different concentrations of alkaline. The ratio of sodium hydroxide to sodium silicate is 1:2, which is kept constant to prepare the mix. To prepare the mix, it is necessary to change the concentration of sodium hydroxide solution to 3, 4, and 6 Mole percentages. Samples were cured for 14, 28 and 56 days and the specimens were tested for mechanical properties to determine the durability of fibre mixtures in concrete. Better results found for the sample dipped in 4 mole for 56 days of curing after testing.
Keywords: Coir, Flax, M30, Alkaline, Mechanical properties.

1. Introduction

Eco- friendly natural fibres can be added to improve the strength, durability and impact resistance of the concrete, making it more resistant to cracking and other damage[1-2]. This could reduce maintenance costs and improve the life of the concrete. The fibres could also help to reduce the weight of the concrete, making it easier to transport and install. The last few decades have seen an increase in demand for sustainable building materials as a result of the trend of environmental awareness in building materials development. [4–6]. Natural fibres are inherently sustainable due to benefits such as renewability, biodegradability, low dependence on non-renewable energy sources, and low emission of pollutants [3,4,7–10]. Lastly, there have been socio-economic developments in the tropical areas of Latin America and South Asia, such as migration to the urban environment [7], that sparked research interest into natural fibres. As a highly available material which incurs very few production costs and allows use of local labor, natural fibres are a suitable building material for low-cost housing in the impoverished rural areas [1,7,11,12].

As a novel building material, natural fibres have brought a set of limitations and difficulties of their own, which are often the topic of scientific research. Many report the highly heterogeneous nature of the material [4] and water absorption capability, which causes swelling and shrinking and ultimately debonding of the fibres and the binder [10]. The most challenging element relates to the instability of natural fibres in the alkaline environment of the cement matrix [1,22,23]. This is defined as an interaction of alkali attack on fibres; the latter being greatly enhanced by the high water absorption capacity of fibres. Alkali attacks may affect natural fibres on several structural levels. Whereas degradation often starts as decomposition of lignin and hemicellulose components, which are associated with the fibre surface [22], advanced degradation will also affect the fibre's structural cellulose polymer chains [1,24

The aim of this work is therefore to characterize short-term degradation of natural fibres in the alkaline cement composites, with the logic that knowing how and where degradation starts, seeking solutions to prevent it may become more effective. Understanding short-term degradation can aid in the expansion of the use of natural fibers as sustainable fibrous materials in the building industry.

1.1 Significance of work

The significance of fiber mixed concrete in alkaline testing procedures lies in its enhanced durability and resistance to chemical attacks. The fibers help to bridge micro-cracks and reduce permeability, thereby increasing the concrete's longevity and performance in alkaline environments.

2. Related work

Libo Yan et.al.(2016) studied the use of coir fibers as reinforcement materials for cementitious composites and studied the behavior of untreated and treated alkali coir fibers in concrete. Studies were done using a scanning electronic microscope (SEM) to look at the microstructures of untreated and treated coir fibers. Kochova et.al. (2019) demonstrates that a composite made of coir fibers has appropriate mechanical and thermal characteristics. Pre-treated fibers provide a better cement contact and less slide behaviour than untreated coir fiber. Madueke, C.I., Kolawole (2021) study explores the density, tensile properties, water absorption, and porosity of coir fibers from Sri Lanka. The tensile strength and stiffness decreased with increasing gauge length, while the elongation at break increased. The porosity and cell structure of coir fibers were studied using scanning electron microscopy and thermogravimetric analysis to understand the changes in mechanical properties and failure modes. K. Raja Karthikeyan et.al. (2022), in their study about the influence of coir fiber treatment on the mechanical characteristics of a coir fiber reinforced epoxy composite. When compared to untreated coir composites, the mechanical characteristics of treated coir hybrid composites improved. Mohammed, A et.al. (2023) developed composite materials made from flax fiber reinforced with expanded polystyrene wastes are low-cost, lightweight, eco-friendly and will be reduced environmental pollution. Dugvekar, M., & Dixit, S. (2022) studied the Coir fibers and various techniques applied to improve the surface interaction of these fibers. The treatment techniques include silane treatment, effect of coupling agents and their effect on the strength of composites. These techniques help to improve the fiber-matrix adhesion, makes the fiber surface clean and rough, reduce the water absorption of Coir fibers. Panwar, A., & Neelakrishnan, S. (2021), an experimental study has been conducted to assess the possibility of minimizing these variations by optimizing the surface treatment parameters. Coir fibers were subjected to NaOH treatment at various concentrations, time, and temperature parameters as ascertained by the Box-Behnken design. Tasgin, Y., Demircan, G (2024) investigated the mechanical, wear and thermal properties of NFRCs incorporating cotton, sisal, coir and wool fibers. V.Pandyaraj, L.Ravi Kumar (2018) studied the GFRP composite is reinforced with Flax and coir to get a new combination of material. The Mechanical properties like tensile strength, flexural behavior and impact strength of GFRP reinforced with coir and GFRP reinforced with Flax were studied. Prasanna Raut, Devakant Baviskar (2024) studies on natural composites, particularly those reinforced with flax fibers, has gained traction due to their eco-friendliness, light weight, and relatively good mechanical properties. Flax fibers are known for their high specific strength, stiffness, and biodegradability, making them an ideal candidate for sustainable composite materials.

3. METHODOLOGY

This experimental study aims to examine the properties of concrete mix with flax and coir to improve mechanical properties. In order to make the mixture, the ratio of sodium hydroxide to sodium silicate is maintained at 1:2, and the ratio of alkaline liquid to binder is set at 0.70, by varying the concentration of sodium hydroxide solution from 3 to 4 and 6 M. The prepared moulds are heated at 60ºC for 24 hours and placed it for sunlight curing. Specimens were tested for compression, split tensile and flexural at an age of 14, 28 and 56 days.

3.1 Materials Selection:

Two types of fibres are taken in the present mix, namely coir and flax fibre. The properties after fibre treatment are given in table 1.

Table 1: Physical properties of fibres in present work after treatment

S.No	Property	Coir	Flax
1	Density- g/cm^3	1.2	1.55
2	Diameter- mm	0.3	0.2
3	Water absorption	15%	9.1%
4	Elongation	3%	2 %
5	Moisture resign	10.5%	12%
6	Tensile strength - Mpa	21.5	28.6
7	Specific gravity - kg/m^3	2.63	1.95
8	Shear strength - Mpa	14.57	11.76
9	Flexural strength -Mpa	20	9.76

10	Compressive strength - Mpa	26.2	30

3.1.1 Alkaline liquid: The sodium hydroxide and sodium silicate solution was the alkaline liquid that was utilised. Since potassium-based treatments are more expensive, sodium-based solutions are preferred. Sodium hydroxide (NaOH) flakes of commercial quality, with a purity level of 97% to 98% of the NaOH and $Na_2 SiO_3$ solution. The flakes are dissolved in water to make an alkaline solution.

3.1.1.2 Acid evaluation Test

Exposure to acidic environment leads to degradation of concrete. To study the effects of the acid attack, the specimens were given exposure to the Sulphuric acid (H_2SO_4) and the test was carried out as per Indian standard of testing. Sulphuric acid of 5% by weight of water was taken as the medium and the specimens were submerged in it. The concentration of the medium was maintained by replacing at day 1, day 3 and then at every 7 days.

3.1.2 Aggregates: The coarse aggregates have been made using crushed 10 mm and 20 mm stones that are accessible in the region. Use of clean, locally-sourced river sand as a fine aggregate is common practice.

Parameters for mix design:

- Target Strength – M30
- Type of Cement - OPC 43
- Degree of Supervision - Good
- Type of Aggregate -Crushed Angular
- Maximum Nominal Aggregate Size - 20mm

Casting and curing of specimens

The combinations that produced the most cohesive and workable concrete were determined by casting and testing of hybrid specimens. The curing procedure, amount of aggregate, sodium hydroxide solution and Sulfuric acid have an impact on how strong and long-lasting the natural- fibre concrete. The ratio of sodium hydroxide to other substances often falls between 1.5 and 2.5; 2.5 was chosen for this study. A ratio of 0.45 between activator solutions and coir with flax mixture was chosen. Same water-to-cement ratio and maximum aggregate size were used in the mix design. Dry components, including coarse aggregates (in SSD condition), fine aggregates, and cement (for related mixes), were combined for 2.5 minutes in the mixer. The super plasticizer and alkaline solution were combined for 2.5 minutes to ensure homogeneity after being added for 1 minute.

The cylinder samples sized (Figure 1)150 mm diameter x 300 mm length, the Cube sizes (Figure 1) 150 x 150 x 150 mm and the beam size (Figure 2) as 150 x 150 x 500mm.

Figure 1: Cube and Cylinder samples

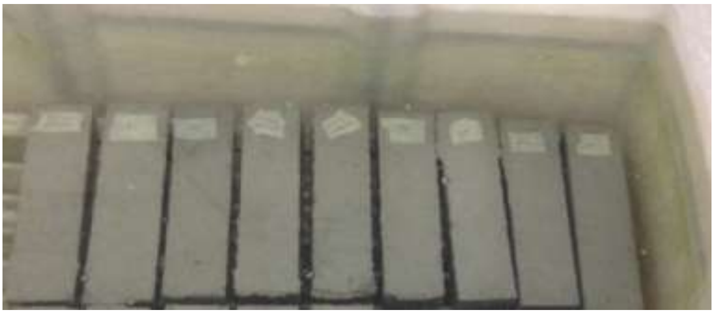

Figure 2: Beam samples

4. RESULTS AND DISCUSSIONS:

The experimental program included the assessment of durability parameters, such as resistance to chemical attack and permeability, to ensure the long-term performance of the coir in concrete with flax.

4.1 Compressive Strength test

The procedure involves preparing concrete cubes with varying percentages of alkaline additives. Once the cubes have cured, they are placed in a compression testing machine, where a steadily increasing force is applied until the cubes fracture. The maximum force applied at the point of fracture is recorded to assess the compressive strength of the cubes for each alkaline percentage. The test results for testing of cubes at different curing ages given in the table 2. The maximum compressive strength attained was 33.9MPa for 56 days, the increase of compressive strength found to be 30% when compared with 14 days of curing 23.8 M Pa . Compare to others a 5-8% increment in strength found as given in table2.

Table 2: Compressive strength

Mix ratio	Compressive strength (MPa)		
	14 Days	28 Days	56 Days
3 M	22.9	30.2	33.4
4 M	23.8	30.6	33.9
6 M	22.1	29.8	32.8

4.2 Split tensile strength test

The testing procedure involves preparing cylindrical concrete specimens with varying percentages of alkaline materials added to the mix. These specimens are then cured for a specified period before being placed in a split tensile testing machine. The machine applies a compressive load along the diameter of each cylinder until failure occurs, allowing the tensile strength to be calculated from the maximum load applied. The results obtained for an average of three specimens given in the table3. The maximum split tensile strength is 4.5 MPa, an increment of 25% in strength attained after 56 days.

Table 3: Split Tensile test

Mix ratio	Split Tensile Test (MPa)		
	14Days	28Days	56 Days
3 M	3.15	3.8	4.3
4 M	3.30	3.9	4.5
6 M	3.12	3.5	4.2

4.3 Flexural test

To conduct the flexural test, fiber concrete specimens are prepared with varying alkaline percentages and are molded into standard beam shapes. These beams are then placed on a testing apparatus where a load is applied at a constant rate until the specimen fails. The load and deflection data collected during the test are used to evaluate the flexural strength and toughness of the concrete. The results obtained given in the table 4, for 56 days at a maximum of 4.4MPa achieved for 4M alkaline solution.

Table 4: Flexural Test

Mix ratio	Flexural Test (MPa)		
	14Days	28Days	56 Days
3 M	3.12	3.5	4.3
4 M	3.24	3.6	4.4
6 M	2.96	3.4	4.1

5. SEM analysis of fractured samples after testing

Specimens designed for hybrid concrete samples of 1% flax and 3% of coir tested for durability after 56 days. The specimens are also exposed for acidic and alkaline testing to check the biodegradability in shape and surface using Standard electronic microscopy. Three specimens tested for bio degradable affect at different mole percentages. Results of the samples analyzed for surface and absorption qualities as a part of durability.

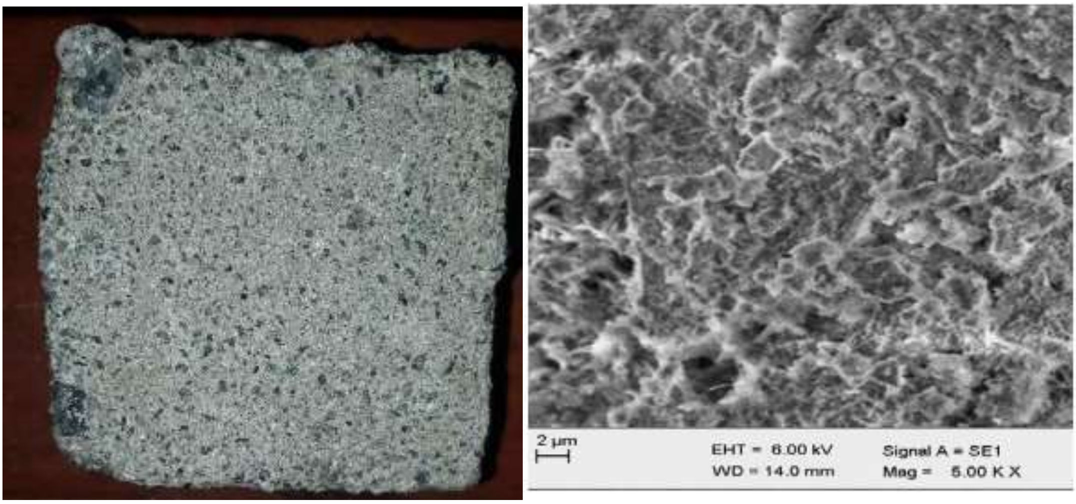

Figure:3 Specimen dipped in 3M for 56 days

Microstructures were analyzed for void filling nature of fibre after alkaline treatment, this nature of C- H bonding between concrete and the aggregates taken for the mix as shown in figure 3. The C-S-H formed with binder after durability test very less number of pi formation with good porosity observed. After 56 days of curing in alkaline solution with 4 M percentage as shown in figure 4 fibre occupancy in the area of voids and pits covered by the fibre, this C-S-H formation with sodium and calisium successfully filled the pit gaps, the chloride affect on hybrid concrete is very less when compared with normal curing.

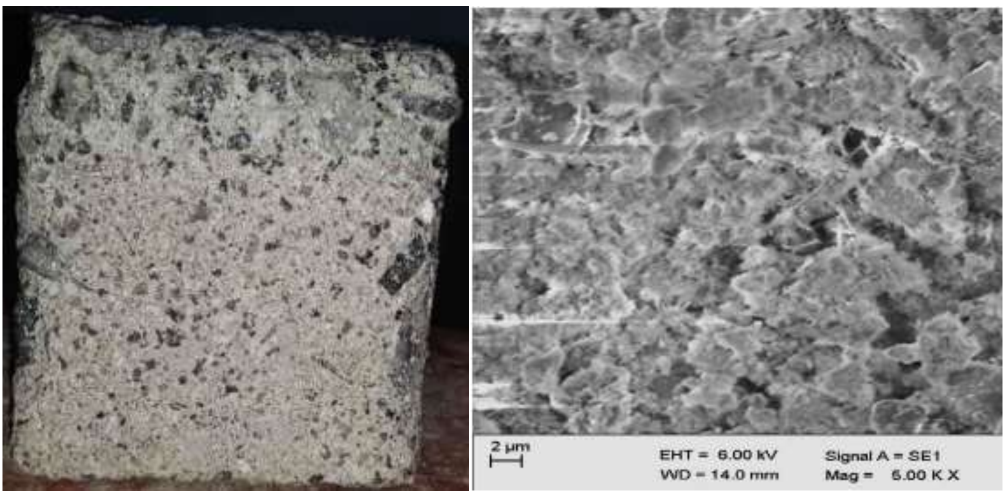

Figure:4 Specimen dipped in 4M for 56 days

Increasing alkaline percentage affected the durability and strength, more pits and voids found in the sample and this may affect the mechanical properties of the sample as shown in figure5.

Even though, the amount of Ca(OH)2 is lesser due to pozzolanic reaction, the voids are more due to reduced formation of hydration products as cement content got decreased.

Figure: 5Specimen dipped in 6M for 56 days

The comparative analysis of alkane samples with regular cooling samples to check the deviation in mechanical properties are given in the table5.

Table5: Comparison of durability samples

Days of curing	Compressive (MPa)			Split tensile (MPa)			Flexural (MPa)		
	N-C	A-C	Acid	N-C	A-C	Acid	N-C	A-C	Acid
14	24.4	23.8	22.45	3.3	3.3	2.56	3.3	3.24	2.96
28	30.8	30.6	29.44	3.6	3.9	2.94	3.8	3.6	3.34
56	34.8	33.9	33.62	4.7	4.5	3.55	4.6	4.4	3.97

Note: N-C represent normal water curing, A-C alkaline acidity curing

6. Conclusions

The mechanical tests of specimens subjected to alkaline and acidic environments were carried out at 14, 28 and 56 days of immersion and the results obtained were compared with compressive strength of those 56 days water cured specimens which are not exposed to the acidic environment. Alkaline percentages can significantly influence the properties of fiber concrete, including its strength and durability. Higher alkaline levels may enhance the bonding between fibers and the cement matrix, potentially increasing the flexural strength. However, excessive alkalinity could lead to deterioration or reduced performance over time, highlighting the importance of optimal balance. Compare with natural curing the table5 reflects the results showing that a 2 to 3% variation in strength decrement in alkaline attack and a 10% decrement in acidic attack. In all cases, for all the mixes, the percentage reduction in strength went on increasing with the increase in exposure duration to sulphuric acid. This is because fibre mixed concrete is more dense and has a higher resistance to cracking. This makes it more resistant to alkaline degradation, resulting in better results in alkaline testing.

References

1. Libo Yan et.al. (2016), Effect of alkali treatment on microstructure and mechanical properties of coir fibres, coir fibre reinforced-polymer composites, and reinforced- cementitious composites, Construction and Building Materials, Vol.112, pp 168–182.
2. K. Kochova et.al. (2019), Using alternative waste coir fibres as a reinforcement in cement-fibre composites, Construction and Building Materials, Vol. 231, pp. 117121
3. Verma, D., & Gope, P. C. (2015). The use of coir/coconut fibers as reinforcements in composites. Biofiber Reinforcements in Composite Materials, 285–319. doi:10.1533/9781782421276.3.285 10.1533/9781782421276.3.285
4. Mahzabin, M. S., Jee Hock, L., Siong Kang, L., & Nikbakht Jarghouyeh, E. (2019). Behaviour of kenaf fibre reinforced composite. IOP Conference Series: Materials Science and Engineering, 513, 012006. doi:10.1088/1757-899x/513/1/012006
5. Adeniyi, A. G., Onifade, D. V., Ighalo, J. O., & Adeoye, A. S. (2019). A review of coir fiber reinforced polymer composites, Composites Part B, 107305.
6. Madueke, C.I., Kolawole, F. & Tile, J. RETRACTED ARTICLE: Property evaluations of coir fibres for use as reinforcement in composites. SN Appl. Sci. 3, 262 (2021). https://doi.org/10.1007/s42452-021-04283-3
7. K. Raja Karthikeyan, K. Tamilmannan, S. Socrates, Experimental investigation on the coconut fiber reinforced hybrid gear composites, Materials today proceedings, Volume 62, Part 2, 2022, Pages 1252-1255
8. Rajesh, D.; Lenin, N.; Cep, R.; Anand, P.; Elangovan, M. Experimental Investigation of Bi-Directional Flax with Ramie Fibre-Reinforced Phenol-Formaldehyde Hybrid Composites. Polymers 2022, 14, 4887. https://doi.org/10.3390/polym14224887
9. Mohammed, A., & Rao, D. N. (2023). Investigation on mechanical properties of flax fiber/expanded polystyrene waste composites. Heliyon, 9(3), e13310. https://doi.org/10.1016/j.heliyon.2023.e13310.
10. Dugvekar, M., & Dixit, S. (2022). Chemical Treatments for Modification of the Surface Morphology of Coir Fiber: A Review. Journal of Natural Fibers, 19(15), 11940–11961. https://doi.org/10.1080/15440478.2022.2048938
11. Panwar, A., & Neelakrishnan, S. (2021). An Experimental Study on the Effect of Mercerization Parameters on the Variation in the Chemical Composition and Mechanical Properties of Natural Fibers: Coir. Journal of Natural Fibers, 19(15), 10383–10393. https://doi.org/10.1080/15440478.2021.1993505
12. Tasgin, Y., Demircan, G., Kandemir, S. et al. Mechanical, wear and thermal properties of natural fiber-reinforced epoxy composite: cotton, sisal, coir and wool fibers. J Mater Sci 59, 10844–10857 (2024). https://doi.org/10.1007/s10853-024-09810-2
13. V.Pandyaraj, L.Ravi Kumar and D. Chandramohan, Experimental Investigation of Mechanical Properties of GFRP Reinforced with Coir and Flax, International Journal of Mechanical Engineering and Technology, 9(12), 2018, pp. 1034–1042.
14. Hasan, K.M.F., Horváth, P.G., Kóczán, Z. et al. Thermo-mechanical properties of pretreated coir fiber and fibrous chips reinforced multilayered composites. Sci Rep 11, 3618 (2021). https://doi.org/10.1038/s41598-021-83140-0.
15. Prasanna Raut, Devakant Baviskar (2024) Study of Natural Composites with Flax Fiber Through Finite Element Analysis, International Journal of Research Publication and Reviews, Vol 5, no 1, pp 4705-4711.
16. ASTM C 642-06. Standard Test method for Density, Absorption, and Voids in Hardened Concrete. West Conshohocken, Pennsylvania, United States
17. ASTM C 267-97. Standard Test Methods for Chemical Resistance of Mortars,Grouts and Monolithic Surfacings and Polymer Concretes. West 128 Conshohocken, Pennsylvania, United States. (Source: http://www.scribd.com/doc/230862 438/C267)

18. ASTM C 579-01. Standard Test Methods for Compressive Strength of Chemical resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes. West Conshohocken, Pennsylvania, United States. (Source: http://www.scribd.co m/doc/250467834/229667661-ASTM-C-579#scribd
19. Hwang, C.L., Bui, L.A.T., & Chen, C.T. (2011). Effect of rice husk ash on the strength and durability characteristics of concrete. Construction and building materials, 25(9), 3768-3772, DOI: 10.1016/j.conbuildmat.2011.04.009.
20. Alex, J., Dhanalakshmi, J., & Ambedkar, B. (2016). Experimental investigation on rice husk ash as cement replacement on concrete production. Construction and Building Materials, 127, 353-362, DOI: 10.1016/j.conbuild mat.2016.09.150
21. Chusilp, N., Jaturapitakkul, C., & Kiattikomol, K. (2009). Utilization of bagasse ash as a pozzolanic material in concrete. Construction and Building Materials, 23(11), 3352-3358, DOI: 10.1016/j.conbuildmat.2009.06.030
22. Ganesan, K., Rajagopal, K., & Thangavel, K. (2007). Evaluation of bagasse ash as supplementary cementitious material. Cement and concrete composites, 29(6), 515-524, DOI: 10.1016/j.cemconcomp.2007.03.001.
23. Balagopal, V., & Sambamurthy, V. (2020). Performance Evaluation of Coir Pith Ash Blended Cement Concrete Exposed to Elevated Temperature. Jurnal Teknologi, 82(2).
24. Balagopal, V., and Viswanathan T. S. (2020), " Effect of Elevated Temperature on Performance of Concrete Containing Supplementary Cementitious Material Derived from Coir Industry". International Journal of Emerging Trends in Engineering Research, 8(8), 4496 – 4501