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Durability Characteristics and Microstructural Properties of Concrete Reinforced with Coconut Fibre

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ABSTRACT

The increasing demand for sustainable construction materials has encouraged research into natural fibres as alternatives to conventional reinforcement materials in concrete. Coconut fibre, an agricultural waste material with favourable physical and mechanical properties, has considerable potential for improving the sustainability and durability of concrete. This study investigated the durability characteristics and microstructural properties of concrete reinforced with different coconut fibre contents, with emphasis on water absorption, water permeability, sulphate resistance, acid resistance, freeze–thaw resistance, and microstructural development. Concrete specimens containing 0%, 0.5%, 1.0%, and 1.5% coconut fibre were produced and tested at specified curing and exposure periods. The coconut fibre was characterised based on its physical and mechanical properties, while the aggregates were assessed for suitability for concrete production. Durability assessments included water absorption, water permeability, sulphate resistance, acid resistance, and freeze–thaw tests. Microstructural investigations were conducted using Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), and X-Ray Diffraction (XRD) to evaluate morphology, fibre–matrix interaction, elemental composition, and crystalline phases. The results showed that the coconut fibre had a length of approximately 15–30 cm, diameter of 0.1–0.5 mm, density of 1.15–1.46 g/cm³, tensile strength of 100–250 MPa, aspect ratio of approximately 400:1, and Young's modulus of 7.50 GPa. The 0.5% fibre mixture recorded the lowest water absorption at 28 days (4.6%), compared with 6.1% for the control mixture. The reported water permeability coefficient progressively decreased from 2.6×10^{-4} to 7.1×10^{-5}. Under sulphate exposure, the 0.5% mixture exhibited the highest mass retention at 28 days, while acid exposure produced surface discolouration and changes in specimen mass. After 100 freeze–thaw cycles between −18°C and +4°C, no visible surface cracking occurred, although strength reduction indicated possible internal deterioration. SEM analysis showed that the 0.5% mixture developed a comparatively dense and homogeneous matrix with improved fibre–matrix contact at 90 days, whereas higher fibre contents exhibited greater heterogeneity and residual pores. EDS and XRD analyses confirmed calcium-, silicon-, aluminium-, and oxygen-rich matrices containing crystalline phases such as quartz, anorthite, albite, orthoclase, calcite, and muscovite. The study concludes that coconut fibre can enhance the durability and microstructural characteristics of concrete, with performance dependent on fibre content. The 0.5% mixture demonstrated the most favourable overall response among the mixtures investigated, particularly in water absorption and sulphate resistance, indicating the potential of coconut fibre as a sustainable reinforcement material for concrete.

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INTRODUCTION

Concrete is widely used because of its versatility and availability, but its quasi-brittle response and susceptibility to cracking can facilitate ingress of water and aggressive species. Fibre reinforcement can bridge cracks and modify post-cracking behaviour; natural fibres also offer a potentially renewable route to valorise agricultural residues. Coir is a lignocellulosic fibre with relatively high lignin content and reported toughness, yet its hydrophilicity, variability, alkaline exposure and interfacial compatibility can create durability and workability challenges.

Prior work cited in the source dissertation describes fibre dosage, fibre treatment, dispersion and interfacial transition-zone (ITZ) properties as controlling factors in natural-fibre cement composites. A moderate dosage may bridge microcracks, whereas excessive addition may increase entrapped air, fibre clustering and connected porosity. Microstructural evidence is therefore useful for interpreting measured transport and exposure behaviour, but SEM morphology alone does not identify phases; elemental or diffraction measurements are complementary.

The present work examines coconut-fibre-reinforced concrete (CFRC) at 0–1.5% dosage, focusing on material characterization, water uptake and permeability, sulphate/acid exposure, freeze–thaw response, and SEM–EDS/XRD findings. The principal contribution claimed here is an integrated account of the study's durability and microstructural observations, with limitations made explicit where the source record does not support a definitive quantitative inference.

Aims and Objectives

The aim of this study is to evaluate the durability performance and microstructural behavior of concrete reinforced with coconut fibre, in order to determine its potential as a sustainable and cost-effective alternative to conventional reinforcement materials in construction.

The specific objectives are to:

i. characterize the material to be used
ii. assess the durability properties of coconut fibre on reinforced concrete, and
iii. carry out microstructure investigation of coconut fibre on reinforced concrete.

Significance of Study

The use of natural fibres as sustainable alternatives in concrete technology has gained momentum due to growing environmental concerns and the need for eco-friendly construction materials. This study on the durability characteristics and microstructural properties of concrete reinforced with coconut fibre is significant for several reasons.

It has contributed widely to sustainable construction practices by exploring the use of agricultural waste "coconut fibre" as a reinforcing material. Coconut fibre is a biodegradable, renewable, and abundant resource in tropical regions, particularly in countries like Nigeria, India, and the Philippines. Utilizing this waste product in concrete production not only helps reduce environmental pollution but also promotes a circular economy (Ali et al., 2012).

The study provides insight into how coconut fibre influences the durability of concrete, including its resistance to water penetration, chloride attack, shrinkage, and freeze-thaw cycles. These parameters are critical in determining the long-term performance and maintenance cost of concrete structures, especially in aggressive environmental conditions.The research investigates the microstructural behavior of fibre-reinforced concrete, helping to understand the bonding mechanisms between the coconut fibre and the cement matrix. Microstructural analysis using techniques such as Scanning Electron Microscopy (SEM) can reveal how fibre inclusion affects crack propagation and internal densification, which are vital for improving toughness and crack resistance (Arif et al., 2016).This study can serve as a reference for engineers, builders, and policymakers interested in sustainable building materials, offering data-driven insights into the mechanical and microstructural benefits of coconut fibre in concrete composites. This could lead to more widespread application of natural fibre composites in low-cost housing, pavements, and non-structural elements, thereby promoting both performance efficiency and environmental conservation.

MATERIALS AND METHODS

Materials and Mix Proportions

Ordinary Portland cement (reported as ASTM C150 Type I), clean river sand (ASTM C33), crushed granite with a maximum size of 20 mm, potable water, and locally sourced coconut fibre were used. The dissertation describes a nominal 1:2:4 mix and water–cement ratio of 0.50. Fibre contents were 0, 0.5,1.0 and 1.5%; the mix-proportion table expresses fibre mass as 0, 0.0284, 0.0568 and 0.0852 kg against 5.68 kg cement, 37 kg fine aggregate, 65.1 kg coarse aggregate and 2.84 kg water. Thus the batching was done by mass.

Table 1: Mix Proportions of Concrete Containing Different Coconut Fibre Contents

Mix	Cement (kg)	Fine agg. (kg)	Coarse agg. (kg)	Water (kg)	Fibre (kg)	w/c
0%	5.68	37	65.1	2.84	0	0.50
0.5%	5.68	37	65.1	2.84	0.0284	0.50
1.0%	5.68	37	65.1	2.84	0.0568	0.50
1.5%	5.68	37	65.1	2.84	0.0852	0.50

Coconut fibres was:

i. Extracted from mature coconut husk
ii. Washed and sun-dried
iii. Cut to lengths of 25mm, 50mm and 75 mm

The following fibre treatment methods was employed:

i. Untreated (control)
ii. Alkali Treatment: Soaking in 5% NaOH solution for 24 hours.
iii. Hot Water Treatment: Immersion in 100°C water for 1 hour
iv. Oven drying
v. Epoxy resin treatment / Silane Treatment: Coating with epoxy resin and hardener mixed together for 1-2minutes before application on Coir to improve chemical bonding



Figure 1: Coconut Husk/Coir Preparation Shown in the Dissertation (Source Figure; Reused from the Author's Project)



Figure 2: Oven Drying Process

Casting and Curing

Concrete was mixed and cast as cubes (150mm by 150mm by 150mm) cured for 7,14 and 28days for the durability test section. The microstructural specimens were cured for 28 and 90 days at 23 ± 2 °C. The dissertation's batching, mixing and casting photographs are represented in Figure 3.



Figure 3: Cast Specimens from the Experimental Work, Illustrating Batching/Casting and Specimen Preparation (Source Image)

Aggregate and Fibre Characterization

Fine and coarse aggregates were assessed for specific gravity, bulk density, absorption, moisture and grading-related properties. Coconut fibre characteristics were reported as typical values/descriptions rather than a traceable set of replicate measurements. The reported fibre properties are presented below:

Table 2: Physical properties of fine and Coarse Aggregates of Coconut Fibre

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.64	2.67
Bulk density (reported units as kg/m³)	1667.90	1642.67
Water absorption (%)	2.00	2.04
Moisture content (%)	0	0
Curvature coefficient	0.88	1.00
Coefficient of uniformity	3.00	2.43
Fineness modulus	2.70	—

Table 3: Reported Characteristics of Coconut Fibre

Fibre property	Reported value
Length	15–30 cm typical; 25/50/75 mm cut lengths also specified
Diameter	0.1–0.5 mm
Density	1.15–1.46 g/cm³
Tensile strength	100–250 MPa (typical range)
Aspect ratio	approximately 400:1
Young's modulus	7.50 GPa
Water absorption / moisture	approximately 100% absorption; 8% moisture (reported)

Durability Testing

Water absorption was determined at 7, 14 and 28 days from reported dry and wet masses, with percentage values tabulated by mix. Water permeability was evaluated with a standpipe arrangement; reported specimen length was 15 cm, standpipe area 0.288 cm^2, specimen volume 3375 cm^3 and specimen area 180 cm^2. Five head-drop readings and permeability coefficients were reported.

For chemical resistance, cubes were immersed in 5% Na_2SO 5% , H_2SO_4 for 7, 14 and 28 days; specimen mass and visual appearance were recorded. Freeze–thaw testing was described as 100 cycles between −18 and +4 °C, with surface cracking, mass loss and strength reduction assessed, citing ASTM C666.

Microstructural and Phase Analyses

SEM was described as conducted under vacuum at magnifications of 100×–10,000× after fragments were dried at 50 °C for 48 h and sputter-coated with gold or carbon. The reported micrographs include 8,000×–10,000× images at 20 kV, with scale bars of 20–100 µm. EDS was used to estimate elemental composition at selected regions. Powder XRD was described using Cu Kα radiation, approximately 2θ = 5–70° (some results state 3–70°), 0.02° step size and 1°/min scan speed. It reported phase identification against reference patterns; detailed calibration, replicate sampling and the quantification protocol. The specimens were cut into 75 mm after curing for 28days and 90 days respectively to evaluate the microstructural properties.

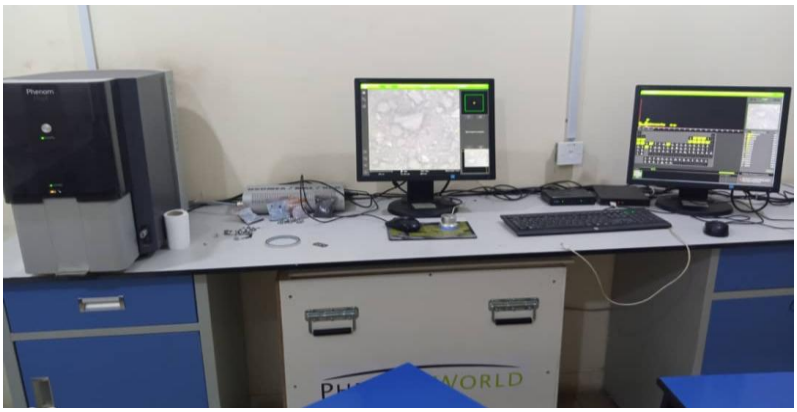


Figure 4: Scanning Electron Microscopy (SEM)



Figure 5: Experimental Workflow Evidence: Preparation and Casting. (Image is Reused from the Source Dissertation; Full Workflow Described in Sections 2.1–2.5.)

RESULTS AND DISCUSSION

Materials Characterization

Aggregate specific gravity and fine-aggregate fineness modulus are consistent with ordinary natural aggregate ranges, while aggregate water absorptions are approximately 2%. The dissertation concludes that the aggregates were suitable for concrete. Coir's low density and high reported aspect ratio make it a plausible crack-bridging reinforcement; its high water uptake, however can change effective mixing water and local porosity unless preconditioning and moisture correction are controlled.

Water Absorption and Permeability

Table 4: Water Absorption (%) of Coconut-Fibre-Reinforced Concrete at Different Curing Ages

Age	0%	0.5%	1.0%	1.5%
7 days	0	0	0	0
14 days	6.2%	3.6%	6.1%	3.6%
28 days	6.1%	4.6%	5.9%	5.9%

The table above shows the results of the concrete water absorption with varying mix design of coconut fibre. For the concrete mixes at 0%, 0.5%, 1% and 1.5% mixes for 7 , 14 and 28 days, it displays the percentage of water absorption; the corresponding values are 0%, 0%, 0%, 0% for 7days, 6.2%, 3.6%, 6.1% and 3.6%, for 14days and 6.1%, 4.6%, 5.9% and 5.9% for 28 days respectively. The results indicate that the wet weights were slightly higher than the corresponding dry weights at 7 days. This suggests that all the specimens absorbed a small quantity of water during the test. The differences between dry and wet weights were approximately 0.05 kg for all fibre contents. Thus, the specimens demonstrated broadly similar short-term moisture uptake at this age.

The results also indicate that coconut fibre influenced the moisture uptake characteristics of the concrete. At 14 days, the 0.5% and 1.5% mixtures exhibited lower reported absorption than the control and 1.0% mixture. At 28 days, the 0.5% mixture again produced the lowest reported water absorption, while the 1.0% and 1.5% mixtures exhibited values close to that of the control. This suggests that a relatively low fibre content may provide a more favourable modification of the concrete pore structure, whereas increasing fibre content beyond an optimum level does not necessarily improve water absorption performance.

Overall, the results suggest that 0.5% coconut fibre produced the most favourable water absorption performance among the tested mixtures, particularly at 14 and 28 days.

Table 5: Water Permeability Test Results for the Concrete Specimen

Test No	Initial stand pipe ht (H1) mm	Final stand pipe ht (H2)mm	Elapsed time (t2-t1) (secs)	L/(T2-T1)	Loge $\frac{H1}{H2}$	K = $\frac{al}{A(T2-T1)\ \log e\ \frac{H1}{H2}}$
1	900	800	11	1.364	0.1179	2.6X10^-4
2	800	700	23	0.632	0.1837	1.9X10^-4
3	700	600	37	0.1542	0.1542	1.0X10^-4
4	600	500	53	0.1842	0.1842	8.34X10^-5
5	500	400	75	0.2231	0.2231	7.1X10^-5

The water permeability test was conducted to assess the resistance of the concrete to water penetration under an applied hydraulic condition. The test provides an indication of the ease with which water can move through the interconnected pores of the concrete.

The specimen had a reported length of 15 cm, standpipe area of 0.288 cm², specimen volume of 3,375 cm³, and specimen area of 180 cm²

The results show a progressive reduction in the reported coefficient of permeability as the elapsed time increased. The coefficient decreased from 2.6×10^{-4} in Test 1 to 7.1×10^{-5} in Test 5.

This indicates that the rate of water movement through the specimen reduced as the hydraulic head declined. The result suggests increasing resistance to water flow during the test.

The test gave a minimum and maximum specification of 8.34×10^{-5} and 1.0×10^{-4}, respectively, and an average coefficient of permeability of 1.4088×10^{-4}.



Figure 6: Water Permeability Testing Apparatus

Sulphate and Acid Exposure

Table 6: Mass of Coconut-Fibre-Reinforced Concrete Specimens Following Sodium Sulphate and Sulphuric Acid

Exposure	Mix fibre (%)	7 d mass (kg)	14 d mass (kg)	28 d mass (kg)
5% Na_2SO_4	0.5	8.75	8.75	8.61
	1.0	8.65	8.65	8.22
	1.5	8.05	8.10	8.00
5% H_2SO_4	0.5	8.65	8.65	8.22

Exposure	Mix fibre (%)	7 d mass (kg)	14 d mass (kg)	28 d mass (kg)
	1.0	8.45	8.45	8.20
	1.5	8.25	8.45	8.22

The sulphate and acid resistance test was performed by immersing concrete cubes in a 5% Na_2SO_4 and 5% sulphuric acid (H_2SO_4)solution for periods of 7, 14 and 28 days. The purpose was to assess changes in specimen mass and surface condition following sulphate exposure and to evaluate changes in mass and visible deterioration resulting from acid exposure. The initial weight was 8.00 kg

The sulphate resistance results indicate that exposure to 5% sodium sulphate solution produced changes in the mass of the coconut-fibre-reinforced concrete specimens. At 28 days, the 0.5% fibre mixture retained the highest mass of 8.61 kg, followed by the 1.0% and 1.5% mixtures with masses of 8.22 and 8.00 kg, respectively. The reduction in mass with increasing exposure duration was more pronounced in the higher fibre-content mixture. After 28days, a yellowish surface coloration was observed which indicated that chemical interaction occurred during sulphate exposure. Based on mass retention, the 0.5% mixture demonstrated the most favourable performance among the fibre-reinforced mixtures investigated while the acid resistance results demonstrate that exposure to 5% sulphuric acid produced measurable changes in the mass and surface appearance of the concrete specimens. The masses recorded at 7 and 14 days were relatively stable for each mixture, whereas a reduction was observed at 28 days. At 28 days, the 1.0% mixture recorded the lowest mass of 8.20 kg, while the 0.5% and 1.5% mixtures recorded 8.22 kg indicating that prolonged acid exposure produced greater changes in specimen mass. The specimen showed a slight discoloration at 7 and 14 days and a more pronounced yellowish colouration after 28 days, which was attributed to chemical reaction during acid exposure.



Figure 6: Showing Sulfuric Acid (H_2SO_4) Solution



Figure 7: Showing the Immersion of 5% Sulfuric Acid (H_2SO_4) Solution for 7-28 Days



Figure 8: Showing the Na_2SO_4 and the 5% Na_2SO_4 Solution



Figure 9: Showing the Immersion of Cubes in 5% Na_2SO_4 Solution for 7-28 days

Freeze–Thaw Response

The test was carried out with the cube specimen been subjected to 100 cycles of freezing and thawing (from -18°C to +4°C) in accordance with ASTM C666 to assess Surface cracking, Mass loss and Strength reduction.

Table 7: Showing the Results After Freezing

Initial weight (kg)	After freezing weight (kg)
8.77 kg	8.88 kg

The recorded initial mass was 8.77 kg, while the mass after freezing was 8.88 kg.

The freeze–thaw resistance test showed that the specimen mass increased from 8.77 kg before exposure to 8.88 kg after 100 freeze–thaw cycles, representing an increase of approximately 1.25% (0.11kg). No visible surface cracks were observed following exposure, indicating that the specimen maintained its external integrity under the test conditions. However, a reduction in strength occurred after the freeze–thaw cycles, suggesting that internal deterioration may have occurred despite the absence of visible surface cracking. The increase in mass may be associated with moisture retention or uptake within the pore structure during the freeze–thaw process.



Figure 9: Showing the Weighing Balance for Measuring the Weight after Freezing



Figure 10: Showing a Freeze thaw Resistance Testing Apparatus

SEM Morphology and Fibre–Matrix Interface

The scanning electron microscopy (SEM) results revealed variations in the microstructural characteristics of concrete containing 0%, 0.5%, 1.0%, and 1.5% treated coconut fibre at 28 and 90 days of curing. At 28 days, the control specimen exhibited a relatively compact cementitious matrix with localized pores and microstructural discontinuities. The 0.5% fibre mixture showed comparatively well-bonded regions, although residual pores and interfacial irregularities remained. The 1.0% mixture displayed a heterogeneous matrix with visible particulate phases and localized voids, while the 1.5% mixture exhibited pronounced particle agglomeration, surface irregularities, and greater microstructural heterogeneity. These observations suggest that increasing fibre content influenced the distribution and morphology of the cementitious matrix, with higher fibre incorporation associated with more evident structural irregularities.

At 90 days, all mixtures showed signs of continued microstructural development, characterized by improved matrix continuity and a reduction in the prominence of some visible voids. The control specimen exhibited a more consolidated matrix, while the 0.5% and 1.0% mixtures showed further development of the cementitious matrix around the embedded fibre regions. The 1.5% mixture also demonstrated improved matrix continuity; however, localized pores and interfacial discontinuities persisted. Overall, the SEM observations indicate that prolonged curing was associated with microstructural development across the investigated mixtures, while the extent of heterogeneity varied with fibre content. The findings highlight the importance of fibre dosage in achieving a balance between matrix compactness and effective fibre–matrix interaction. Nevertheless, phase identification and confirmation of hydration products require complementary techniques, such as energy-dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD).

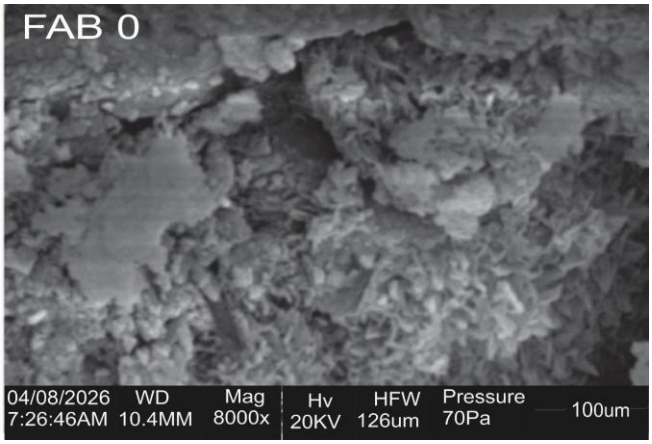


Figure 11: SEM Source Micrograph: Control Concrete (0%; Source Image Extracted from the Dissertation)

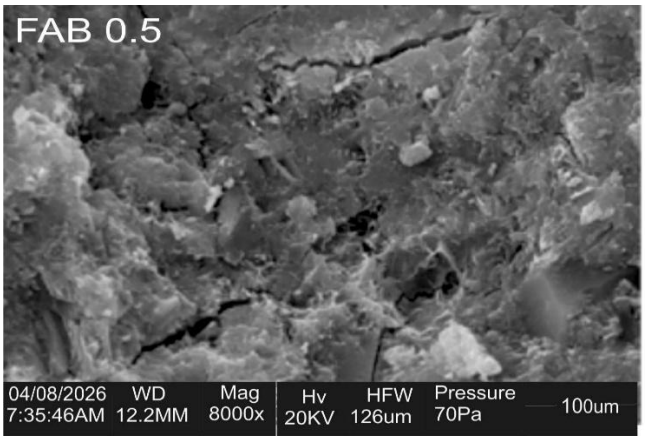


Figure 12: SEM Source Micrograph: 0.5% Coconut-Fibre Mixture (Source Image Extracted from the Dissertation)

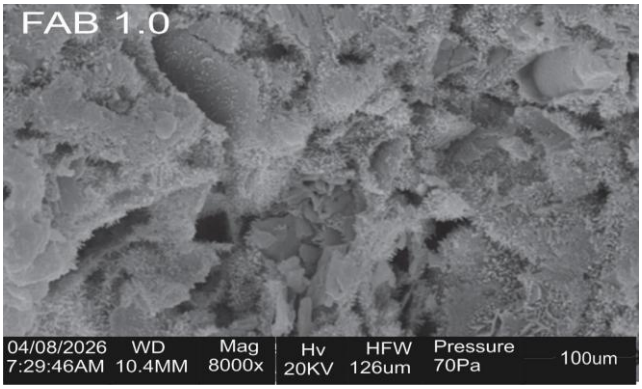


Figure 13: SEM Source Micrograph: 1.0% Mixture (Source Image Extracted from the Dissertation)

EDS Elemental Composition

SEM–EDS analysis was conducted to determine the elemental composition of the concrete specimens incorporating 0%, 0.5%, 1.0% and 1.5% coconut fibre for 28days and 90days curing. The results revealed calcium (Ca), silicon (Si), aluminium (Al) and oxygen (O) as the principal elements across the analysed specimens, although their relative concentrations varied with fibre content. The control specimen exhibited Ca, Si and Al concentrations of 45.00, 23.69 and 15.13 wt.%, respectively. At 0.5% fibre content, calcium increased to 83.48 wt.%, accompanied by lower concentrations of Si (2.45 wt.%) and Al (1.15 wt.%). The 1.0% specimen recorded Ca, Si, Al and O concentrations of 32.00, 21.10, 14.40 and 21.00 wt.%, respectively, while the 1.5% specimen contained 50.10 wt.% Ca, 20.60 wt.% Si, 10.86 wt.% Al and 8.30 wt.% O. Minor quantities of Na, K, Fe and Mg were also detected.

The predominance of calcium, together with the presence of silicon, aluminium and oxygen, is consistent with the occurrence of calcium-bearing silicate and aluminosilicate constituents in the cementitious matrix. However, the pronounced variation in elemental concentrations suggests chemical heterogeneity among the analysed regions. The calcium-rich composition of the 0.5% specimen may reflect the localised presence of calcium-bearing phases rather than a uniform change in the bulk material. When interpreted

alongside the SEM micrographs, the EDS results provide complementary evidence of variations in the local chemical composition of the concrete matrix with increasing coconut fibre content.

XRD Phase Analysis

X-ray diffraction (XRD) analysis for the 28days and 90 days curing revealed a multiphase crystalline structure in the concrete specimens containing 0%, 0.5%, 1.0% and 1.5% coconut fibre. The principal crystalline phases identified were quartz, anorthite, albite, orthoclase, calcite and muscovite. Quartz was the dominant phase across the fibre-incorporated specimens, with the principal diffraction reflections occurring around $2\theta = 26.8–28.2°$. Quantitative phase analysis showed that quartz accounted for 53 ± 7 wt.% in the 0.5% specimen, 55 ± 13 wt.% in the 1.0% specimen and 67 ± 8 wt.% in the 1.5% specimen. Anorthite contents were estimated at 24 ± 4%, 22 ± 18% and 15 ± 6%, respectively, while calcite accounted for 16 ± 3%, 7.2 ± 1.8% and 4 ± 2%.

The results indicate variations in the relative proportions of the identified crystalline phases with increasing coconut fibre content. The presence of quartz reflects the silica-bearing mineral constituents, while anorthite, albite and orthoclase represent calcium-, sodium- and potassium-bearing aluminosilicate phases, respectively. Calcite indicates the presence of crystalline calcium carbonate, whereas muscovite represents a potassium- and aluminium-bearing mica phase. These findings are broadly consistent with the elemental constituents identified by SEM–EDS and confirm the heterogeneous mineralogical composition of the specimens.

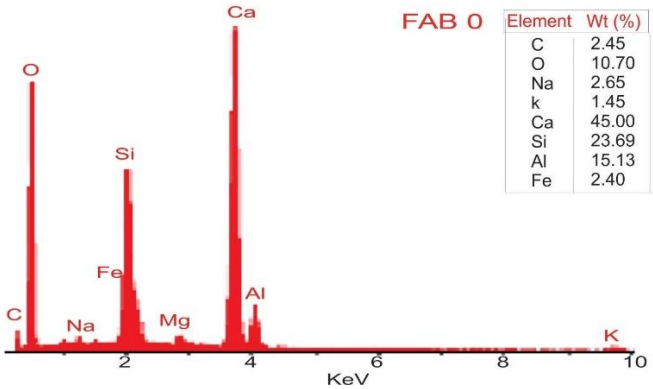


Figure 14: Representative XRD Pattern Reproduced from the Dissertation Source (Control, Specimen;Phase,Attribution)

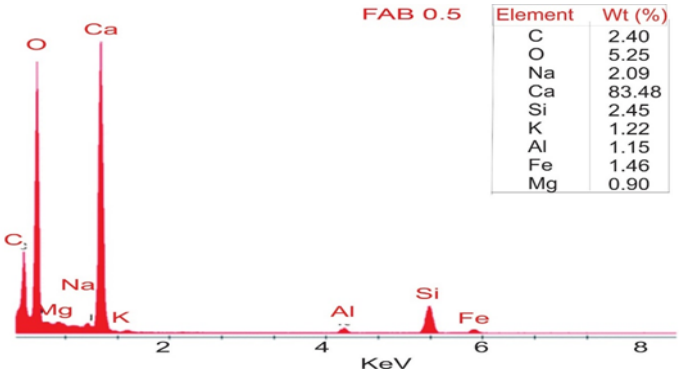


Figure 15: Representative XRD Pattern Reproduced from the Dissertation Source (0.5% Specimen; Phase Attribution Follows the Source's Reported Analysis)

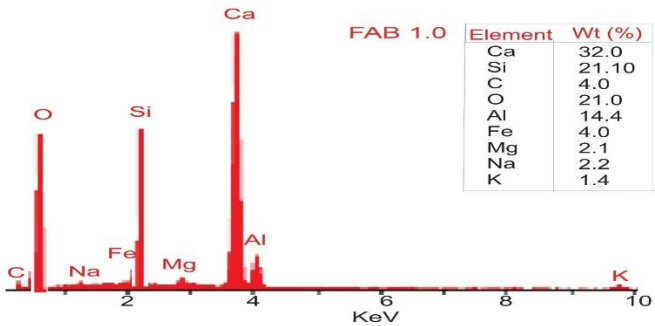


Figure 16: Representative XRD Pattern Reproduced from the Dissertation Source (1% Specimen; Phase Attribution Follows the Source's Reported Analysis)

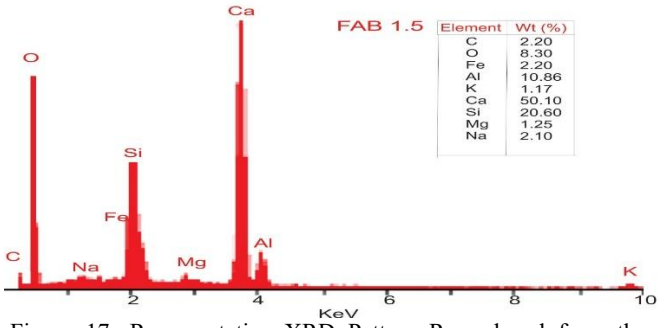


Figure 17: Representative XRD Pattern Reproduced from the Dissertation Source (1.5% Specimen; Phase Attribution Follows the Source's Reported Analysis)

Integrated Discussion

The study demonstrated that coconut fibre content influences the durability and microstructural characteristics of concrete, with 0.5% fibre providing the most favourable overall performance among the dosages investigated. This mixture recorded the lowest 28-day water absorption (4.6%), compared with 6.1% for the control, and the highest reported mass after sulphate exposure (8.61 kg). SEM analysis revealed a comparatively compact and homogeneous matrix at 0.5% fibre content, whereas the 1.0% and 1.5% mixtures exhibited greater heterogeneity, fibre agglomeration and localised porosity. These microstructural features are consistent with the observed variations in moisture resistance. EDS identified calcium, silicon, aluminium and oxygen as the principal elements, while XRD revealed crystalline phases comprising quartz, anorthite, albite, orthoclase, calcite and muscovite. Although permeability decreased during testing, the acid- and freeze–thaw-resistance results did not establish a consistent advantage across all fibre dosages. Overall, the results suggest that controlled fibre incorporation and adequate dispersion are essential for improving selected durability characteristics. A 0.5% coconut fibre content was considered the most promising dosage within the range studied.

CONCLUSIONS

The investigated study used nominal 1:2:4 concrete at w/c = 0.50 and coconut-fibre contents of 0, 0.5, 1.0 and 1.5%, with microstructural examinations reported at 28 and 90 days.

Fine and coarse aggregates had reported specific gravities of 2.64 and 2.67 and absorption values of 2.00 and 2.04%; reported coir properties include 0.1–0.5 mm diameter, 1.15–1.46 g/cm³ density, 100–250 MPa tensile strength and 7.50 GPa modulus.

The 0.5% mixture had the lowest reported 28-day water absorption (4.6% vs 6.1% control), but underlying dry/wet mass data contain inconsistencies that require verification.

Reported 5% sulphate and acid exposure results include mass changes and yellowish discoloration. Because masses often exceed the stated initial weight and control exposures are absent, mass-retention conclusions are provisional.

After the reported 100 freeze–thaw cycles, one specimen showed no visible cracking and mass increased 1.25%; strength change was not numerically documented.

SEM descriptions indicate a comparatively dense 0.5% matrix at 90 days and greater heterogeneity at higher fibre content. EDS and XRD support the reported presence of Ca–Si–Al–O-rich regions and multiple crystalline phases, but analytical details and quantification require validation.

Overall, 0.5% is a promising dosage among those tested, not a statistically proven optimum. The dataset should be reconciled and replicated before any publication-level claim of improved durability is made.

Limitations and Recommendations for Publication

Based on the findings of this study, a coconut fibre content of 0.5% is recommended because it provided the most favourable balance of durability and microstructural performance among the fibre contents investigated. Coconut fibres should be properly cleaned, dried, conditioned, and uniformly dispersed before mixing to minimize agglomeration, localized void formation, and unintended changes in the effective water–cement ratio. Higher fibre contents should not automatically be assumed to improve durability, as increasing the fibre content to 1.0% and 1.5% was associated with greater microstructural heterogeneity and localized porosity. In addition, the use of coconut fibre reinforced concrete should be supported by appropriate quality control during mixing and compaction, while structural applications should be based on verified mechanical and durability performance for the specific mix design.

Where coconut fibre reinforced concrete is intended for acidic or sulphate-rich environments, additional protective measures should be considered because prolonged chemical exposure produced changes in specimen mass and surface appearance. Future studies should investigate fibre treatment methods such as alkali treatment, coatings, and other surface-modification techniques to improve fibre–matrix bonding and reduce deterioration in the alkaline cement environment. Further research should also extend durability assessments beyond 28 and 90 days under aggressive exposure conditions and employ replicated specimens with statistical analysis to establish the significance of differences between the control and fibre-reinforced mixtures.

Contribution to Knowledge

The study contributed to knowledge by providing empirical evidence on the influence of coconut fibre content on the durability characteristics of concrete, thereby addressing the objective of determining the effect of fibre incorporation on concrete performance. The findings established that 0.5% coconut fibre provided the most favourable overall durability response among the 0%, 0.5%, 1.0% and 1.5% mixtures investigated, particularly with respect to water absorption and resistance to sulphate exposure. The study further established that increasing coconut fibre content beyond the optimum level did not result in a corresponding improvement in durability, as higher fibre contents were associated with increased fibre agglomeration, pore formation and interfacial discontinuities. This finding provided a basis for identifying a controlled fibre dosage for improving the durability performance of coconut fibre reinforced concrete.

In relation to the objective of evaluating the microstructural properties and fibre–matrix interaction of the concrete, the study contributed knowledge by establishing a direct relationship between observed microstructural characteristics and measured durability performance. SEM examination revealed that the 0.5% fibre mixture developed a comparatively compact and dense matrix, while continued curing enhanced hydration-product development and fibre–matrix contact, thereby promoting matrix continuity and potential stress transfer. The integrated application of SEM, EDS and XRD further provided complementary evidence of the morphological, elemental and mineralogical characteristics of the concrete, confirming the predominance of Ca–Si–Al–O constituents and identifying major crystalline phases within the cementitious matrix. Collectively, these findings provided experimental evidence that controlled incorporation of coconut fibre can improve the durability and microstructural characteristics of concrete while demonstrating its potential as a locally available and sustainable reinforcement material for construction applications.

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The source dissertation identifies Prof. C.A. Fapohunda as supervisor and Federal University Oye-Ekiti, Nigeria, as the institution.All authors declare no conflict of interest in any form with other people or organization that could inappropriately influence, or be perceived to influence, this research work.

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