# Performance of coir fibre-reinforced concrete incorporating crushed coconut shells as a partial replacement for coarse aggregates

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## ABSTRACT

The increasing demand for sustainable construction materials has intensified the exploration of agricultural waste as viable alternatives to conventional concrete constituents. This study investigates the durability performance of coir fibre-reinforced concrete incorporating crushed coconut shell aggregates (CCSA) as partial replacements for conventional coarse aggregates. An experimental research design was adopted in which concrete mixes with varying proportions of CCSA and coir fibres were prepared and evaluated. Durability performance was assessed through water absorption, density, crack resistance, and non-destructive testing methods, including Schmidt Hammer rebound and Ultrasonic Pulse Velocity (UPV) tests, to evaluate surface hardness, internal integrity, and resistance to micro-cracking. The results show that increasing CCSA content reduces workability and density due to its high water absorption and lower specific gravity compared to conventional aggregates, while improving sustainability through reduced reliance on natural stone. However, the incorporation of coir fibres enhances cohesion, reduces segregation, and improves crack resistance through fibre-bridging mechanisms that limit micro-crack propagation. The combined use of UPV and Schmidt Hammer tests indicated variations in internal integrity and surface hardness across the tested mixes. The reported findings suggest that moderate CCSA replacement levels of 10–20%, combined with controlled coir fibre content, offer a potential balance between crack resistance and durability performance. However, thermal exposure reduced flexural strength across the tested mixes, while saline exposure revealed variations in surface hardness and compressive strength with coir fibre content. The findings demonstrate that the performance of concrete incorporating crushed coconut shells and coir fibres depends on the proportions used and the environmental exposure conditions. It is recommended that CCSA replacement levels not exceeding 20%, combined with coir fibre contents of approximately 0.2–0.3%, be considered for further evaluation through long-term durability testing under relevant environmental exposure conditions before wider structural application. This study contributes to the understanding of the potential use of agricultural waste in concrete production, supporting resource efficiency and sustainable construction practices, particularly in regions with abundant coconut waste resources. It is recommended that crushed coconut shell aggregate replacement levels not exceed 20%, combined with coir fibre contents of approximately 0.2–0.3%, and that these mixes undergo long-term durability testing under relevant environmental exposure conditions before being considered for wider structural application.

**Key words:** Crack Resistance; Durability Performance; Partial Aggregate Replacement, Schmidt Hammer; Sustainable Concrete; Ultrasonic Pulse Velocity

## I. INTRODUCTION

The construction sector remains one of the largest consumers of natural resources and a major contributor to environmental degradation due to the extensive use of conventional materials such as cement, sand, and crushed stone. Rapid urbanization and infrastructure development have significantly increased the demand for these materials, leading to depletion of natural aggregates, rising construction costs, and increased carbon emissions. These challenges are particularly pronounced in developing countries, where material extraction and transportation heavily influence project costs and environmental sustainability (Prakash, et al., 2021). Consequently, there is growing interest in identifying alternative, locally available, and environmentally sustainable construction materials.

In response, research has increasingly focused on the use of agricultural waste and by-products in concrete production as a means of reducing environmental impact while maintaining acceptable engineering performance (Mutnbak, 2026). Among these materials, CCSA and coir fibres have attracted attention due to their abundance, low cost, and favorable material properties. Coconut shells, when processed and used as partial replacements for coarse aggregates, can produce lightweight concrete with reduced density and improved thermal properties (Pordesari et al.,



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2021). Coir fibres, derived from coconut husks, exhibit high tensile strength, flexibility, and resistance to degradation, making them suitable as natural reinforcement for enhancing crack resistance and ductility in concrete (Bui *et al*., 2020).

Previous studies have demonstrated that coconut shell aggregates can effectively replace conventional aggregates in lightweight concrete applications, while coir fibres contribute to improved tensile behavior and crack control (Gunasekaran et al., 2015). However, most of these studies have considered these materials independently. There remains limited understanding of their combined performance, particularly with respect to durability characteristics such as permeability, resistance to micro-cracking and long-term structural integrity (Prakash et al., 2021). This gap is significant, as durability is a key factor influencing the service life and maintenance requirements of concrete structures (Amran et al., 2021).

The relevance of this research is particularly evident in Kenya's coastal region, where coconut farming generates substantial quantities of agricultural waste. Counties such as Kilifi, Mombasa, and Kwale produce large volumes of coconut shells and husks, much of which is discarded or left to decompose, leading to environmental challenges (Mwachofi, 2016). The utilization of these materials in concrete presents an opportunity to address both waste management and material scarcity while promoting sustainable construction practices. Moreover, the local availability of these resources makes them economically attractive for use in low- to medium-cost construction. Despite this potential, there is limited locally contextualized data on the durability performance of concrete incorporating coir fibres and crushed coconut shells. Variations in climate, material properties, and construction practices necessitate region-specific studies to ensure safe and effective application (Aili & Maruyama, 2020). In particular, the influence of these materials on permeability, crack propagation, and resistance to environmental deterioration remains insufficiently documented.

The construction industry faces increasing pressure to adopt sustainable materials due to the depletion of natural aggregates, rising costs, and environmental impacts associated with conventional concrete production. In Kenya, the high demand for crushed stone has intensified resource depletion and increased construction costs, while aggregate production contributes to carbon emissions. At the same time, large quantities of agricultural waste such as coconut shells and coir fibres are generated in coastal regions, often leading to environmental challenges due to improper disposal. Although previous studies have shown that coconut shells can be used as lightweight aggregates and coir fibres can improve crack resistance, limited information exists on their combined effect on the durability performance of concrete. In addition, locally contextualized data in Kenya remains scarce, limiting their practical adoption in construction.

### 1.1 Research Objective

The objective of this study was to evaluate the durability performance of coir fibre-reinforced concrete incorporating crushed coconut shells as partial replacements for conventional coarse aggregates.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

The durability of coir fibre-reinforced concrete incorporating crushed coconut shell aggregates (CCSA) depends on aggregate properties, fibre content, pore structure, crack development, and exposure conditions. Coconut shells offer a sustainable alternative to conventional coarse aggregates and may reduce concrete density, while coir fibres can improve crack resistance by bridging developing cracks. However, the overall performance depends on mixture proportions, fibre–matrix bonding, compaction, and resistance to moisture and environmental deterioration (Ahmad et al., 2022).

This study is underpinned by Materials Science Theory and Particle Packing Theory, which explain how material composition, microstructure, and particle arrangement influence concrete durability and crack resistance. Materials Science Theory provides a basis for understanding how crushed coconut shell aggregates (CCSA) and coir fibres affect the cement matrix, interfacial bonding, pore structure, and crack propagation. Coir fibres can improve crack control through fibre bridging, although their effectiveness depends on fibre content, distribution, and bonding with the cement matrix (Ahmad et al., 2022).

Particle Packing Theory explains how aggregate size distribution, particle shape, and packing density influence void content, compaction, and concrete properties (de Larrard, 1999). In this study, the theory helps explain how CCSA replacement and coir fibre content may affect density, water absorption, and the movement of moisture and dissolved salts through concrete. Together, these theoretical perspectives provide a framework for interpreting water absorption, ultrasonic pulse velocity (UPV), Schmidt rebound hammer results, crack development, and performance under thermal and saline exposure, with the actual effects established through experimental testing.



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### 2.2 Empirical Review

Gunasekaran et al. (2012) investigated the long-term compressive and bond strength of coconut shell aggregate concrete under different curing conditions. Their study incorporated ultrasonic pulse velocity (UPV) measurements and microstructural examination, demonstrating the importance of curing and aggregate–cement paste interaction in concrete performance. However, strength development alone does not establish resistance to moisture ingress, saline exposure, or thermal deterioration.

Nadir and Sujatha (2018) examined several durability indicators, including water absorption, permeable pore voids, sorptivity, chloride penetration, abrasion resistance, and chemical attack. Their work demonstrated the importance of evaluating coconut shell aggregate concrete using multiple durability parameters rather than relying solely on strength. The moisture-related characteristics and structure of coconut shell aggregates may influence the movement of water and aggressive substances through concrete. Consequently, increasing CCSA replacement may reduce density but may also affect moisture sensitivity, depending on the resulting pore structure and quality of compaction.

These studies establish the relevance of investigating different CCSA replacement levels. Nevertheless, their findings do not fully explain how varying aggregate replacement interacts with coir fibre content to influence durability under different environmental conditions.

Coir fibres can contribute to crack control by bridging developing cracks and transferring tensile stresses across fracture surfaces. Ahmad et al. (2022), in a review of coconut fibre-reinforced concrete, identified potential improvements in selected mechanical properties, including flexural performance, while noting reduced workability as a possible limitation. Poor fibre dispersion and excessive fibre content may introduce voids or impair compaction, potentially offsetting the benefits of crack bridging.

Crack resistance is important to durability because cracks can provide pathways for water and dissolved salts to penetrate concrete. However, improved crack control does not automatically guarantee reduced permeability or enhanced resistance to every exposure condition. Fibre effectiveness depends on its distribution, bonding with the cementitious matrix, and interaction with the surrounding aggregates.

The combined use of coir fibres and CCSA may therefore produce complementary effects: shell aggregates influence density and pore structure, while fibres may restrict crack propagation. However, their interaction may also affect workability, compaction, and matrix continuity. Mutnbak (2026) similarly highlights the importance of mixture design, moisture sensitivity, and fibre–matrix stability when evaluating coconut shell aggregate and coir fibre concrete. These considerations justify experimentally assessing the combined materials rather than assuming that their individual benefits will necessarily improve overall durability.

Water absorption and density provide complementary information about the physical characteristics of hardened concrete. Water absorption indicates susceptibility to moisture uptake, whereas density helps establish the effect of lightweight aggregate replacement. Neither parameter independently determines durability: lower density does not necessarily indicate poor performance, and higher water absorption does not, by itself, establish the extent of deterioration. Nadir and Sujatha (2018) demonstrated the value of combining moisture-related measurements with tests of chloride penetration, abrasion, and chemical resistance.

UPV and the Schmidt rebound hammer provide additional, non-destructive information about concrete quality. Gunasekaran et al. (2012) used UPV to monitor coconut shell aggregate concrete during curing. However, pulse velocity is influenced by moisture condition, material composition, internal voids, and cracking. Similarly, rebound hammer results reflect surface hardness and can be affected by surface condition and other testing factors. Both methods should therefore complement, rather than replace, direct durability measurements and crack observations.

Environmental exposure also influences concrete performance. Sekar and Kandasamy (2019) investigated coconut shell concrete incorporating coconut fibre using indicators that included water absorption, permeable pore voids, sorptivity, chloride penetration, and elevated-temperature performance. Their study provides relevant evidence for evaluating both moisture-related durability and temperature effects. However, findings remain dependent on the mixture proportions, curing conditions, and exposure procedures used. The performance of one mixture should not automatically be generalised to all combinations of CCSA and coir fibre content.

### 2.3 Research Gap

Existing studies demonstrate the potential of coconut shell aggregates for producing lightweight concrete and of coir fibres for improving crack resistance. Research has also investigated durability indicators in coconut shell concrete and concrete incorporating coconut fibres (Ahmad et al., 2022; Gunasekaran et al., 2012; Nadir & Sujatha, 2018; Sekar & Kandasamy, 2019). However, the combined influence of varying CCSA replacement and coir fibre content on physical properties, crack development, non-destructive test results, and performance under thermal and saline exposure requires further systematic assessment.



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This study addresses the gap by investigating CCSA replacement levels of 0–30% and coir fibre contents of 0–0.75%. It evaluates water absorption, density, crack development, UPV, Schmidt rebound hammer response, and performance under thermal and saline exposure. By examining these indicators together, the study aims to establish how the combined use of CCSA and coir fibres influences concrete durability and crack resistance, thereby providing experimental evidence to support the sustainable use of these materials in concrete production.

## III. METHODOLOGY

### 3.1 Research Design

A laboratory-based experimental design was used to investigate durability performance. The design involved systematic variation of two independent variables: crushed coconut shell (CCS) content and coir fibre content. A control mix (1:2:4 conventional concrete without CCS and coir fibres) was used as a baseline for comparison. A factorial arrangement was adopted to evaluate the individual and combined effects of CCS and coir fibres on durability-related properties of concrete.

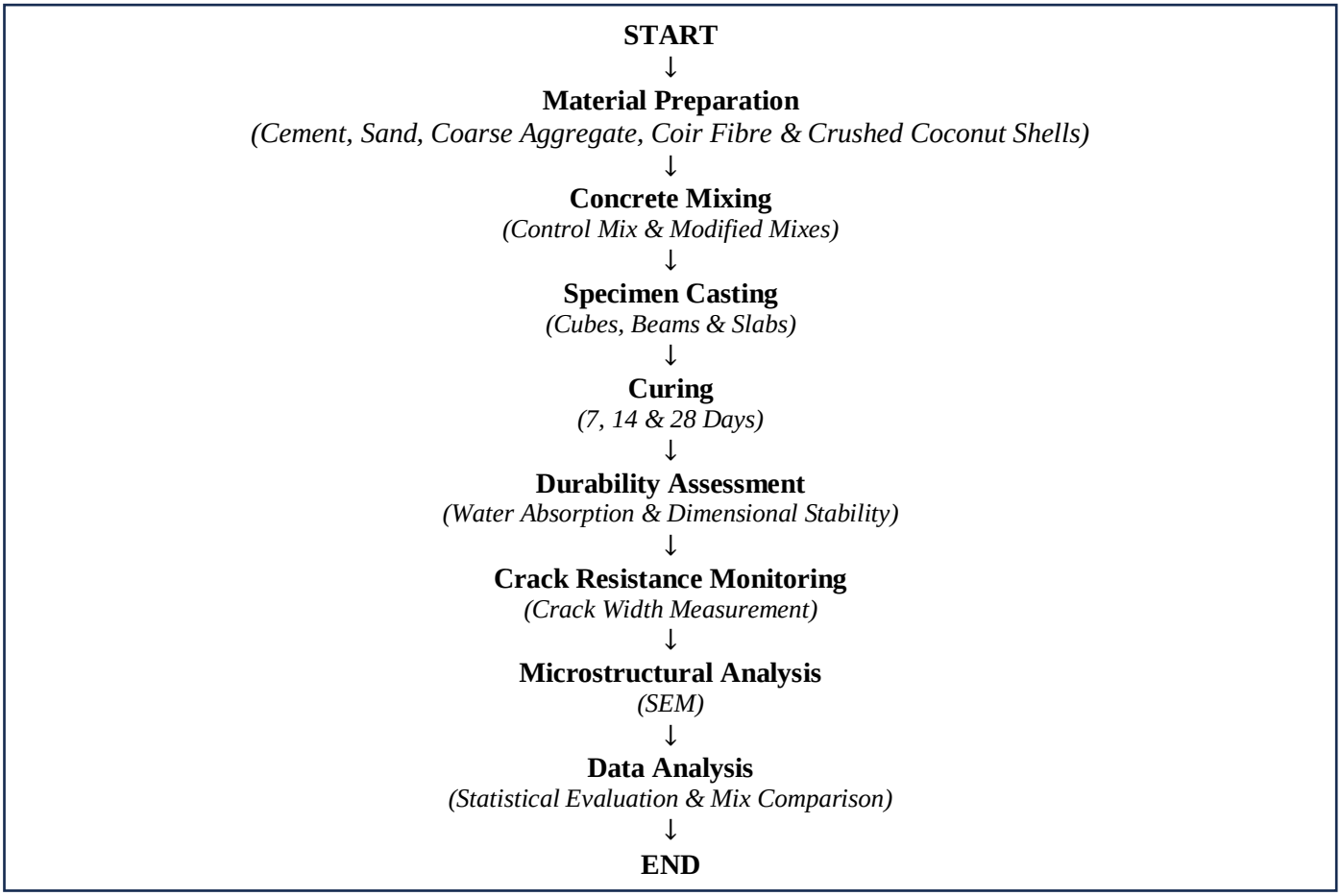



**Figure 1**
*Flowchart of the Experimental Procedure*

Figure 1 presents a flowchart summarizing the step-by-step experimental methodology used in the study, from material preparation through specimen testing and data analysis.

### 3.2 Study Area

The materials used in this study were sourced from the coastal regions of Kenya, specifically Kilifi, Mombasa, and Kwale counties. These areas were selected due to their high availability of coconut resources, which provide both coir fibres and coconut shells as agricultural waste. The experimental work was carried out in a controlled laboratory environment to ensure standardized curing conditions and reliable durability testing results.

### 3.3 Experimental Mix Proportions

The control mix was designed using a standard 1:2:4 concrete ratio. CCS was used as a partial replacement of coarse aggregates at 0%, 10%, 20%, and 30% by volume. Coir fibres were incorporated at 0%, 0.25%, 0.5%, and 0.75%



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by weight of cement. These proportions were selected to assess their influence on durability performance without severely compromising the structural integrity and workability of concrete. The combination of these variables enabled evaluation of how fibre reinforcement interacts with porous CCS aggregates in influencing durability behaviour.

### 3.4 Materials Used

The materials used included ordinary Portland cement, fine aggregates (river sand), conventional coarse aggregates, crushed coconut shells, and coir fibres. CCS was processed by crushing and sieving to match the size range of conventional coarse aggregates, while coir fibres were cleaned and cut to uniform lengths to ensure proper dispersion within the concrete matrix. The use of agricultural waste materials was intended to enhance sustainability while assessing their durability implications.

### 3.5 Sample Preparation and Casting

Concrete batching was carried out using a weight-based method to ensure precision and uniformity. Dry materials were first mixed thoroughly to ensure even distribution of coir fibres and CCS within the mix. Water was then added gradually to achieve a homogeneous mix. Fresh concrete was cast into standard moulds, including 150 mm cubes for durability-related strength assessment and other specimens for absorption and crack resistance tests. Compaction was done using a vibrating table to reduce voids that could affect durability performance.

### 3.6 Curing of Specimens

After casting, specimens were allowed to set for 24 hours before demoulding. They were then cured in water tanks maintained at a controlled temperature of 23 ± 2°C. Curing periods of 7, 14, and 28 days were adopted to evaluate the development of durability characteristics over time. Proper curing was essential to ensure full hydration and to assess how CCS and coir fibres influence long-term resistance to moisture ingress and environmental exposure.

### 3.7 Durability Testing Methods

Durability performance was assessed using standard laboratory tests. Water absorption tests were conducted to determine the rate of moisture ingress into the concrete, which is a key indicator of permeability and long-term durability. Sorptivity-related behaviour was also evaluated to understand capillary water uptake. Crack resistance was assessed through visual monitoring and measurement of crack formation, propagation, and width development during curing and loading. These tests collectively provided insight into the concrete's resistance to environmental deterioration.

### 3.8 Data Analysis

Data obtained from durability tests were analyzed using both descriptive and inferential statistical methods. Descriptive statistics such as mean, standard deviation, and coefficient of variation were used to summarize durability performance results. Inferential analysis using Analysis of Variance (ANOVA) was applied to determine whether differences in CCS and coir fibre content significantly affected durability properties. Regression analysis was used to model the relationship between material composition and durability indicators such as water absorption and crack resistance. A significance level of 0.05 was adopted.

### 3.9 Validity and Reliability

Validity was ensured through the use of standardized testing procedures aligned with ASTM and BS standards for durability testing. Calibration of equipment was carried out before testing to ensure accuracy. Reliability was achieved through replication of specimens for each mix combination, ensuring consistency of results across tests. Multiple samples were tested under identical conditions to minimize experimental error and improve confidence in durability performance trends.

### 3.10 Ethical Considerations

The study adhered to environmental and research ethics by utilizing agricultural waste materials (coir fibres and coconut shells) in a sustainable manner. No human or animal subjects were involved. Material sourcing was done responsibly to ensure no environmental degradation or disruption of local economic activities. The research promoted waste valorisation and environmentally friendly construction practices.



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## IV. FINDINGS & DISCUSSION

### 4.1 Crack Resistance Performance

Ultrasonic Pulse Velocity (UPV): The UPV test was used to assess differences in the internal homogeneity of concrete incorporating coir fibres and crushed coconut shell aggregates (CCS). Higher pulse velocities generally indicate more uniform material, whereas lower velocities may indicate voids, cracks, or other discontinuities. However, UPV is influenced by several factors, including moisture condition, aggregate properties, and test arrangement; it does not independently quantify crack resistance.

**Table 1**

*UPV Test Results for Concrete Samples with Coir and CCS*

| Sample | Distance (mm) | Avg Transit Time (µs) | Avg Velocity (km/s) | Crack Depth ($\times 10^{-5}$ mm) | Crack Width ($\times 10^{-5}$ mm) |
|---|---|---|---|---|---|
| Sample 1 | 70 | 30.1 | 2.33 | 62.70 | 5.63 |
| Sample 3 | 70 | 36.1 | 1.94 | 76.58 | 7.55 |
| Sample 4 | 70 | 31.8 | 2.20 | 68.16 | 4.73 |

Sample 1 recorded the highest UPV (2.33 km/s), followed by Sample 4 (2.20 km/s), while Sample 3 recorded the lowest (1.94 km/s). Sample 3 also had the greatest reported crack depth and width. These differences indicate variation in the ultrasonic response of the specimens. Nevertheless, Sample 1 did not have the lowest reported crack width; Sample 4 recorded the lowest value ($4.73 \times 10^{-5}$ mm). The findings therefore do not support a simple ranking in which higher UPV always corresponds to the smallest crack width.

The reported mix identities are essential for linking these outcomes to the independent variables. If Sample 1 contained 0.3% coir fibre and Sample 3 represented a high-CCS mixture with limited fibre reinforcement, the results may suggest differences associated with mixture composition. However, the three samples alone cannot establish that coir fibres significantly improved crack resistance or that high CCS content caused the observed defects unless their mix proportions and the experimental comparisons are verified. Gunasekaran et al. (2012) investigated coconut-shell aggregate concrete and demonstrated that its performance should be evaluated in relation to material and curing characteristics. Aili and Maruyama (2020) also reviewed how pore structure influences the behaviour of cement-based materials. These studies support interpreting UPV alongside other measurements rather than treating it as a direct measurement of cracks.

#### 4.1.1 Environmental Exposure and Durability Performance

The effects of environmental exposure were assessed through changes in flexural strength following thermal exposure and reported strength and rebound values under saline conditions. These outcomes were examined against coir fibre content and CCS replacement level, where the available data permitted direct comparison. Effect of Temperature Variation on Durability Performance: Concrete specimens were exposed to temperatures of 100–120°C, and flexural strength was measured before and after exposure. Strength retention was calculated as the post-exposure strength divided by the initial strength, multiplied by 100.

$$\text{Strength Retention (\%)} = \frac{\text{Post-exposure Flexural Strength}}{\text{Initial Flexural Strength}} \times 100$$

**Table 2**

*Flexural Strength After Exposure to High Temperatures (100–120°C)*

| Mix Type | Coir % | CCS % | Initial Flexural Strength (MPa) | After Temperature (MPa) |
|---|---|---|---|---|
| Control | - | - | 5.63 | 5.25 |
| Coir 0.1% | 0.1 | - | 4.80 | 2.65 |
| Coir 0.2% | 0.2 | - | 4.11 | 2.21 |
| Coir 0.3% | 0.3 | - | 4.91 | 3.82 |
| CCS 10% | - | 10 | 5.80 | 5.12 |
| CCS 20% | - | 20 | 5.66 | 4.26 |
| CCS 30% | - | 30 | 3.91 | 1.73 |
| Coir 0.3% + CCS 30% | 0.3 | 30 | 4.91 | 3.82 |

The control retained 93.2% of its initial flexural strength, while the 10% CCS mixture retained 88.3%. Retention declined to 75.3% at 20% CCS and 44.2% at 30% CCS. This trend indicates that the higher CCS replacement level was associated with greater proportional strength loss under the reported exposure conditions. However, because the initial



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strengths differed between mixtures, both the absolute residual strength and percentage retention are relevant when comparing performance.

For coir-only mixtures, strength retention was 55.2%, 53.8% and 77.8% at fibre contents of 0.1%, 0.2% and 0.3%, respectively. The 0.3% mixture therefore retained a greater proportion of its initial flexural strength than the two lower-fibre mixtures. This pattern does not support a simple linear relationship between fibre content and thermal performance. Ahmad et al. (2022) reviewed the effects of coconut fibre on concrete properties and highlighted that performance depends on fibre dosage and the property being measured. The present results extend this comparison to residual flexural strength after exposure to 100–120°C. Nevertheless, fibre degradation, increased porosity and weakened aggregate–paste bonding were not directly measured in this experiment; they should therefore be treated as possible explanations rather than established causes.

Effect of Salinity on Durability Performance: The saline-exposure test was intended to assess the performance of coir-modified concrete under marine-like conditions. The reported solution concentration was approximately 35,000 mg/L, which is more accurately described as an approximate seawater salinity or total dissolved solids concentration, rather than a chloride concentration unless chloride was specifically measured. The reported rebound values and average strengths are presented in Table 3.

**Table 3**

*Schmidt Hammer and Strength Results Under Saline Exposure*

| Mix Type | Coir % | Rebound Value (MPa) | Average Strength (MPa) |
|---|---|---|---|
| Control | - | 22.9 | 29.5 |
| Coir 0.1% | 0.1 | 36.8 | 20.0 |
| Coir 0.2% | 0.2 | 25.0 | 24.9 |
| Coir 0.3% | 0.3 | 13.8 | 13.7 |

The control recorded the highest average strength at 29.5 MPa. Among the coir-modified mixtures, the 0.2% fibre mixture recorded the highest strength (24.9 MPa), followed by the 0.1% mixture (20.0 MPa). The 0.3% mixture recorded the lowest strength at 13.7 MPa. In contrast, the 0.1% mixture had the highest reported rebound value (36.8), demonstrating that the rebound and strength results did not follow the same pattern. These results suggest that the mixture containing 0.2% coir fibre performed better in terms of the reported strength than the other fibre-modified mixtures. However, the data do not establish that saline exposure caused the observed strength differences, because corresponding unexposed control results and the exposure duration have not been provided. Without those comparisons, strength retention under saline exposure cannot be calculated. In addition, because the table does not compare CCS replacement levels, the effect of CCS on saline durability cannot be determined from these results.

Ahmad et al. (2022) reviewed the durability performance of coconut-fibre concrete and identified material composition and exposure conditions as important considerations. Aili and Maruyama (2020) also explained that pore structure influences cement-based material durability. These studies provide a basis for examining possible links between fibre content, pore structure and exposure performance. The results show that the relationship between mixture composition and concrete performance varied across the test methods. Rebound values increased with the reported CCS replacement and coir fibre content in the surface-hardness results, whereas the UPV values varied across the three specimens. Thermal strength retention declined from 88.3% at 10% CCS to 44.2% at 30% CCS. Under the reported saline conditions, the 0.2% coir mixture had the highest average strength among the fibre-modified mixtures, while the 0.3% mixture had the lowest.

Taken together, the results do not establish one mixture as the best performer across all durability indicators. Instead, they suggest that the influence of CCS and coir fibre depends on the performance measure considered. This is consistent with Ahmad et al. (2022), whose review describes variable effects of coconut fibres across concrete properties, and with Gunasekaran et al. (2012), who examined the influence of curing and age on coconut-shell aggregate concrete performance. Aili and Maruyama (2020) further explain the importance of pore structure to cement-based material durability.

### 4.2 Summary of Findings in Relation to the Research Variables

The results demonstrate differences in crack-related indicators and strength performance among the tested mixtures. The observed trends indicate that CCS replacement and coir fibre content should be evaluated against individual performance measures rather than assumed to have a uniform effect on durability. No claim of statistical significance is made here because the ANOVA results, replicate counts and associated statistical outputs have not been supplied. If the study did conduct ANOVA, the relevant test statistics, degrees of freedom, exact or appropriately reported p-values, and post-hoc comparisons should be presented before concluding that the independent variables significantly affected the dependent variables.



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**Table 4**

*Relationship between mixture variables and measured performance*

| Research variable | Measured outcome | Main finding |
|---|---|---|
| CCSA replacement level | Thermal strength retention | Decreased from 88.3% at 10% CCSA to 44.2% at 30% CCSA. |
| Coir fibre content | Thermal strength retention | Retention was 55.2%, 53.8% and 77.8% at 0.1%, 0.2% and 0.3%, respectively. |
| Coir fibre content | Strength under saline conditions | The 0.2% mixture recorded the highest average strength among fibre-modified mixtures. |
| Mixture composition | UPV and reported crack dimensions | UPV ranged from 1.94 to 2.33 km/s; Sample 1 had the highest UPV, while Sample 4 had the lowest reported crack width. |
| Mixture composition | Schmidt rebound values and strength | Consistently correspond with strength results. |

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

The study evaluated the durability performance and crack resistance of coir fibre-reinforced concrete incorporating crushed coconut shell aggregates (CCSA). The results showed that Schmidt Hammer values generally increased with CCSA replacement and coir fibre content, while UPV results varied across the tested specimens. Following thermal exposure, flexural strength retention decreased from 88.3% at 10% CCSA to 44.2% at 30% CCSA. Under the reported saline conditions, the 0.2% coir fibre mixture recorded the highest average strength among the fibre-modified mixtures, while the 0.3% mixture recorded the lowest. These findings demonstrate that concrete performance depends on mixture composition and the test conditions. The study indicates that coir fibres and CCSA have potential for sustainable concrete production, but their effects vary across durability indicators. The results do not conclusively establish an optimum combined mixture or statistically significant improvements in durability. Further verification of the experimental data and additional testing are necessary before definitive conclusions can be made regarding the long-term performance of these concrete mixtures.

### 5.2 Recommendations

Based on the findings, CCSA replacement levels of 10–20% and coir fibre contents of 0.2–0.3% may be prioritised for further experimental evaluation. These ranges should not be treated as universally optimal until validated through controlled mix-design trials assessing strength, crack resistance, workability, and durability under the intended service conditions. Higher CCSA replacement levels should be investigated carefully because the 30% CCSA mixture recorded the lowest flexural strength retention among the CCSA-only mixtures after thermal exposure.

Further research should evaluate the combined effects of CCSA and coir fibre using adequate specimen replicates, factorial experimental designs, and appropriate statistical analysis. Additional tests should include water absorption, permeability, direct crack-width measurements, prolonged saline exposure, and thermal cycling. The reported UPV crack dimensions, Schmidt Hammer units, and duplicated thermal-exposure results should also be verified against the original laboratory records to ensure reliable conclusions and practical recommendations.

### Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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