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Research Article

Experimental Study on the Strength Behavior of Concrete Reinforced with Cornhusk Fiber

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Abstract

Concrete is widely recognized as one of the most durable construction materials; however, it is often exposed to harsh environmental conditions that can compromise its mechanical performance. This experimental study evaluated and compared the mechanical properties of fiber-reinforced concrete incorporating cornhusk fiber (CHF) and glass fiber (GF) under varying loads and environmental exposures. Three levels of CHF (0.5%, 1.0%, and 1.5% by mass of cementitious material) and an optimized GF dosage (0.1% by volume of concrete) were examined. Concrete cylinder specimens were cast and monitored for structural performance over 75 and 150 days under two exposure conditions: laboratory-controlled (in-lab) and natural outdoor environments. The mechanical properties assessed included compressive strength and splitting tensile strength. The findings indicated that concrete reinforced with 0.1% GF (GFRC) exhibited the highest 28-day compressive strength among all samples. Among CHF-reinforced concrete (CHFRC) mixtures, the 0.5% CHF dosage demonstrated superior 28-day compressive strength compared to other CHFRC mixtures. Over time, the 0.5% CHFRC mixture consistently exhibited the highest strength gains under both in-lab and outdoor conditions. In the context of tensile strength testing, GFRC (0.1%) exhibited optimal performance at the 28-day mark. However, among the CHFRC samples, the 1.5% CHFRC mixture demonstrated the highest splitting tensile strength at the 28-day interval. At the 150-day mark of outdoor exposure, the 0.5% CHFRC mixture surpassed all other specimens, including GFRC, thereby underscoring its remarkable long-term performance under natural environmental conditions. These findings underscore the potential of 0.5% CHFRC for practical applications, offering an optimal balance of durability and mechanical strength, particularly under prolonged exposure to environmental stresses.

Keywords: *Concrete, Cornhusk Fiber, Environmental Effect, Compressive Strength, Concrete Age.*

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1. Introduction

Concrete is one of the most widely used construction materials on a global scale. As the demands for development and infrastructure continue to increase, there is a growing need to enhance the intrinsic properties of concrete to promote sustainability and improve its structural performance. Concrete is inherently a brittle material; when subjected to excessive stress, it absorbs the impact by forming cracks (Şahmaran & Li, 2010). The incorporation of short, randomly distributed fibers into the concrete mix is an effective approach to mitigate concerns about its brittleness. The type of fiber, its geometry, quantity, distribution, orientation, and the characteristics of the surrounding matrix are critical factors that influence the properties of fiber-reinforced concrete (FRC) (Sadrinejad et al., 2018). A substantial body of research has demonstrated that, in addition to addressing concerns about brittleness, the incorporation of fibers in concrete has a positive impact on its strength characteristics (J. Ahmad, González-Lezcano, et al., 2022; Babalola et al., 2021; Hassanpour et al., 2012; Jamshaid et al., 2022; Khan et al., 2022; Manikandan et al., 2012; Odia, 2023; Saqib & Saleem, 2021). The American Society for Testing and Materials (ASTM) has established a classification system for fiber-reinforced concrete, which is comprised of four categories: Type I - Steel Fiber-Reinforced Concrete (SFRC), Type II - Glass Fiber-Reinforced Concrete (GFRC), Type III - Synthetic Fiber-Reinforced Concrete (SFRC), and Type IV - Natural Fiber-Reinforced Concrete. The categorization system is outlined in the ASTM International document, ASTM International, ASTM C1116/C1116M-10a(2015) - Standard Specification for Fiber-Reinforced Concrete, which was published in 2015 and is currently in effect. The utilization of natural fibers in concrete is not an arbitrary decision; it is supported by the chemical composition of these fibers, which includes cellulose, lignin, hemicellulose, pectin, wax, and other components. Cellulose, a primary component in this regard, functions as the principal reinforcement element (Chokshi et al., 2022; Torgal & Jalali, 2011). The investigation by Mark and Vincent Oettel focused on the performance of bamboo as a plant fiber in ultra-high-performance concrete (UHPC).The rationale behind this choice was to enhance bonding, reduce alkalinity, and consequently improve durability. To this end, they conducted a series of flexural tests to assess the load-bearing capacity of UHPC reinforced with bamboo fibers. The results of these tests demonstrated significant improvements in performance, with a 37.1% increase for the 1.25% bamboo fiber addition and a 30.9% increase for the 2.5% bamboo fiber addition (Bittner & Oettel, 2022).

Natural fibers (NFs) are generally hydrophilic, meaning they absorb water. This can weaken the bond between the fibers and the cement matrix in composites (Chandrasekar et al., 2017). To address this issue, researchers have explored various methods to enhance the properties of NFs for use in cementitious materials. A review by Chandrasekar et al. (2017) outlined four chemical techniques for NF treatment: acetylation, alkalization, benzoylation, and silane treatment. Among these, alkalization was identified as the most cost-effective and efficient method. Similarly, Ismail et al. reviewed the effects of sodium hydroxide (NaOH) treatment on cellulose-based fibers, including sisal, hemp, and coir. They found that NaOH treatment reduces impurities, particularly non-cellulose components, and improves the fiber's surface structure. These enhancements have been shown to strengthen the bond between fibers and the cement matrix, resulting in enhanced mechanical performance and increased durability of cementitious composites (Herlina Sari et al., 2018; Mir Md et al., 2021; Shah, Jing, et al., 2022; Wubneh et al., 2022; Yilmaz et al., 2016; Yılmaz, 2013).

In a subsequent study, Ismail et al. investigated the use of coir, sisal, and hybrid (coir and sisal) natural fiber-reinforced concrete (NFRC). The researchers explored the utilization of varying fiber lengths, specifically 10mm, 20mm, and 30mm, at different mass percentages relative to the cement content, ranging from 0.5% to 1.5%. The study's findings revealed that, while a 0.5% concentration of 20mm HFRC exhibited the most notable improvement in compressive strength, registering a substantial increase of 35.98%, this concentration resulted in a marginal reduction in tensile strength, decreasing by 2.28%. The split tensile strength test demonstrated that the 1.0% inclusion of 20mm HFRC yielded the most significant enhancement, with an observed increase of 25.48%.In summary, the study's primary conclusion indicated that the 1.0% incorporation of 20mm HFRC represented the optimal choice for enhancing both compressive and tensile strength (Shah, Li, et al., 2022).

Hardjasaputra et al. (2017) conducted an experimental investigation aimed at probing the tensile reinforcement potential of coconut fibers in ultra-lightweight concrete. In their study, they explored different weight percentages of coconut fibers relative to the cement content, specifically 0%, 0.1%, 0.175%, and 0.25%. Utilizing flexural strength tests on 60mm x 60mm x 300mm beam specimens, the findings indicated that the incorporation of 0.175% coconut fibers demonstrated optimal performance in terms of tensile strength and structural rigidity (Hardjasaputra et al., 2017).

While the percentage application of fibers in concrete continues to be explored, some efforts have been made toward exploring the effect of several fiber lengths in concrete. This is primarily due to the fact that the process of incorporating natural fibers in concrete frequently results in agglomeration (Faruk et al., 2014). Consequently, the amount of fiber that can be incorporated is constrained by a phenomenon referred to as "balling," which is the propensity of fibers to intertwine and form balls during the mixing process (Aziz et al., 1987; Zakaria et al., 2017). In a study by Zakaria et al. (2015) the incorporation of jute yarn cuts (10 mm and 15 mm) at a 0.1% dosage by volume as reinforcing fibers in concrete was found to be an effective method of minimizing inadequate distribution and irregular arrangement of natural fibers in the mixture. This approach yielded notable tensile, compressive, and flexural strength outcomes for the concrete (Zakaria et al., 2015).

In a separate scholarly inquiry aimed at evaluating the compressive strength and chloride permeability performance of concrete, various proportions of glass fibers (0.03%, 0.06%, and 0.1% by concrete volume) were incorporated into two different cement grades, specifically M20 and M30, over a monitoring period spanning 180 days. This study observed a reduction in bleeding when glass fibers were introduced, consequently contributing to the mitigation of crack formation. The most noteworthy findings from this investigation revealed that the 0.1% glass fiber admixture exhibited the highest tensile and compressive strengths. Concurrently, in terms of cement permeability, the sample containing 0.03% glass fiber demonstrated the most favorable outcome (Chandramouli et al., 2010).

It is a well-established fact that, under typical conditions, the compressive strength of concrete continues to increase with age after the 28th day of curing, albeit at a reduced rate. This phenomenon can be attributed to the progressive hydration of cement and the concurrent development of a more compact microstructural composition (Seyam & Nemes, 2023). In an exploratory study, the impact of concrete age and coarse aggregate type on compressive strength following exposure to elevated temperatures was investigated. The study utilized crushed clay bricks, expanded glass, and normal quartz aggregates for 28,120 and 240 days. The results for unheated specimens indicated that compressive strength increased with age, attributed to cement hydration and denser microstructure formation. Conversely, concrete comprising quartz aggregates and expanded glass aggregates exhibited a decline in strength that was found to be temperature- and age-dependent. Concrete containing crushed clay bricks, on the other hand, demonstrated enhanced resistance to elevated temperatures, with the observed variations in strength attributed to disparities in aggregate thermal expansion and moisture loss (Seyam & Nemes, 2023).

A review of the extant literature reveals a clear emphasis on the potential for integrating natural fibers into structural concrete, underscoring the necessity for further exploration of cellulose-based fibers. However, a notable lacuna exists in the research concerning cornhusk fiber, a cellulose-based fiber, within the context of structural concrete. While numerous studies have examined the mechanical properties of Fiber-Reinforced Concretes (FRCs), the collective impact of exposure conditions and aging on the temporal evolution of these concretes' strength characteristics has received comparatively less attention. In addressing this research gap, this study aims to assess the impact of cornhusk fiber on the compressive and tensile strength of concrete. Furthermore, it investigates how age and exposure conditions jointly influence the rate of change in these strength properties in cornhusk fiber-reinforced concrete, comparing these outcomes with those of glass fiber-reinforced concrete (GFRC).

This paper aims to examine the strength behavior of concrete containing agricultural residue. To this end, an experimental study was conducted, centered around the use of three different percentages (0.5%, 1.0%, and 1.5% of cementitious material) of natural fiber (cornhusk fiber) and an optimized percentage (0.1% of concrete volume) of synthetic fiber (glass fiber) in structural concrete. All cylinder concrete samples were subjected to a 5-month structural monitoring period under two exposure conditions (in-lab and outside/real).The mechanical assessment of the concrete was conducted by determining the compressive strength and splitting tensile strength.

2. Research Methodology

The research was carried out following the work plan highlighted below:

Samples Preparation

In this study, cornhusk fiber (CHF) and glass fiber (GF) were the primary materials utilized, in conjunction with the essential components of concrete: cement, coarse aggregates, and fine aggregates. The cornhusk waste was obtained from harvested cornfields at Louisiana State University's Alexandria campus.

Figure 1. Collected Cornhusk Residue from Corn Field

According to the extant literature, alkaline treatment was identified as the optimal method for extracting CHF (Herlina Sari et al., 2018). This method resulted in the production of fibers at a rate of 26%–28% of the cornhusk's weight, as depicted in **Figure 1**. The extraction process entailed the following steps:

- The cornhusks were meticulously cleaned to remove corncobs and pedicles, leaving only the husk.
- The husk was then boiled in a 4% sodium hydroxide (NaOH) solution for 60–90 minutes to break down hemicellulose and lignin, leaving cellulose fiber strands.
- The fibers were washed with cool water, spread to minimize entanglement, and left to dry (**Figure 2**).
- A schematic of the process is illustrated in **Figure 3**.

Figure 2. Extracted Fiber from Cornhusk

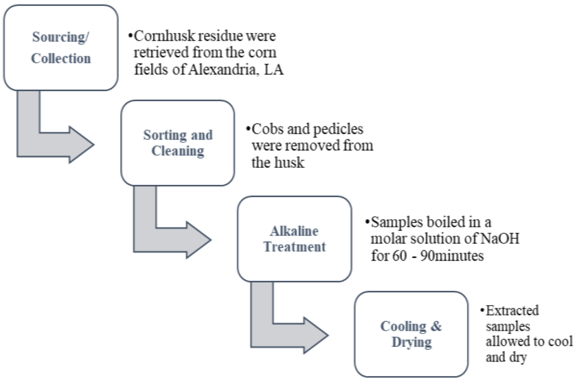

Figure 3. Schematic Illustration of the Alkaline Treatment Process of Cornhusk

To facilitate a comparative analysis with natural fibers, an industry-standard synthetic fiber—Alkali-Resistant High Dispersion (AR) glass fiber—was utilized. This fiber, manufactured by Nycon Industries, complies with (ASTM International, ASTM C1116/C1116M-10a(2015) - Standard Specification for Fiber-Reinforced Concrete, n.d.) at a dosage of 1 lb/cy. The properties of the glass fiber are outlined in **Table 1**.

Table 1. Physical and Mechanical Properties of the AR-HD Glass Fiber

Item	Value
Filament Diameter	0.0005” (0.01mm)
Fiber Length	0.5” (13mm)
Specific Gravity	2.7
Tensile Strength	1551 MPa
Flexural Strength	68,948 MPa
Melting Point	2075F
Color	white
Water Absorption	< 1%
Zirconium	16%
Alkali Resistance	High
Corrosion Resistance	High

Concrete Mix Design

The concrete mix employed in this study was derived from a benchmark (Rupakheti, 2021), which was a standard 1:1:2 mix by volume for M25 high-strength concrete, with a target strength of 25MPa. The concrete samples were prepared using Portland cement type I/II, which complied with the ASTM C-150 specifications. The coarse aggregate used in the mixture was 9.5 mm crushed limestone, as determined by sieve analysis using Gilson Testing Screen equipment. The fine aggregate was fine river sand. The water-cement ratio adopted was 0.47. **Table 2** shows the mix proportions by weight for $0.06m^3$ of concrete, which is the equivalent of nine 1220mm by 2440mm cylinder samples.

Table 2. Concrete Mix Proportion by Weight (1:1:2)

Material	Weight (kg)
Portland Cement	9.45
Fine Aggregate	8.33
Coarse Aggregate	15.98
Water	4.40

Fiber Proportioning

A comprehensive review of the literature on the use of natural fibers to reinforce concrete was conducted, and it was determined that three percentages of CHF reinforcement would be utilized in the study: 0.5%, 1.0%, and 1.5% of the cementitious material (J. Ahmad, Arbili, et al., 2022). Regarding fiberglass, the mix proportion adopted was based on the ACI reference guides, which generally range from 0.01% to 0.25% by volume (ACI Commite 544.3R-08, 2008). **Table 3** presents the weight percentage of the various fiber contents utilized for 0.06m^3 of concrete, which is equivalent to nine-cylinder samples measuring 1220mm by 2440mm. To mitigate the occurrence of balling and ensure the uniform distribution of the CHF in the concrete, the fibers were incorporated into a post-concrete mixture comprising cement, coarse aggregate, and fine aggregate (ACI Commite 544.3R-08, 2008).

Table 3. Amount by Weight of the CHF and Glass Fiber in 0.06m^3 Concrete

Fiber Content	Weight (g)
0.5% CHF	42.6
1.0% CHF	86.2
1.5% CHF	127.0
0.1% FG	38.1

Concrete Samples

The concrete specimens utilized in this study were cylindrical in shape, as specified in the study's scope. Due to the nature of the study, a substantial number of specimens were produced to accommodate tests involving various percentages of fibers, environmental conditions, and sample ages. To ensure the reliability of the results, each test category included three specimens. **Table 4** presents the specimen characterization, and the number of specimens allocated for each test. The samples were prepared using a 0.1m^3. 0.5HP direct drive concrete mixer, in small batches of 0.06m^3, sufficient to produce an equivalent of nine (9) cylinder samples. This approach was adopted to ensure even distribution of the CHF in the concrete. All samples were then subjected to 28-day wet curing, in accordance with the prevailing standards set forth by ASTM (ASTM International, 2000), within a large curing tank equipped with a temperature control system that maintained a constant temperature of 23+/-3°C, as illustrated in **Figure 4.**

Table 4. Total Number of Concrete Cylinder Samples for Experimentation

Fiber Content	Compressive Strength Test					Splitting Tensile Strength Test				
	28th day	Lab		Outside		28th day	Lab		Outside	
		75th day	150th day	75th day	150th day		75th day	150th day	75th day	150th day
0.5% CHF	3	3	3	3	3	3	3	3	3	3
1.0% CHF	3	3	3	3	3	3	3	3	3	3
1.5% CHF	3	3	3	3	3	3	3	3	3	3
0.1% GF	3	3	3	3	3	3	3	3	3	3
Total	120									

Figure 1. Samples subjected to 28 Days of Curing in a Curing Tank

Specimen Curing, Monitoring and Testing

As demonstrated in **Figures 5** and **6**, the experimental design of this study entailed subjecting the concrete specimens to both external environmental conditions and internal laboratory conditions. Subsequent to this, a series of tests and investigations were conducted to ascertain the performance and behavior of the specimens at various ages. For the varying levels of exposure, compressive strength and tensile strength tests were performed on the specimens. The scheduled test times were as follows:

- After wet curing for 28 days (zero-day)
- The 75th day after curing
- The 150th day after curing

The following tests were performed on the prepared specimens with the primary objective of investigating the influence of reinforcement on the structural properties of concrete. These examinations included two critical assessments: compressive strength testing and splitting tensile testing, as outlined below in detail.

Figure 2. Array of Concrete Samples Placed in Lab-controlled Conditions.

Figure 3. Array of Concrete Cylinders in Outside Exposure Condition

Compressive Strength Test of the Concrete Cylinders

The compressive strength test is a pivotal evaluation of concrete's mechanical properties, particularly its compressive strength. According to ASTM C39 (ASTM International, 2018), the compressive strength of CHFRC and GFRC samples containing diverse fibers was assessed using a Universal Testing Machine (UTM). **Figure 7** illustrates this test. The samples were cured for 28 days in water, after which they were tested on the respective scheduled days, 75th and 150th days after the curing period, for both samples that were tested in the laboratory and those that were tested outside. The compressive strength was calculated.

$$f_{cm} = \frac{4P_{max}}{\pi D^2} \qquad (1)$$

where f_{cm} = compressive strength, (MPa), P_{max} = maximum load, (N), D = average diameter, (mm)

Figure 4. Crushed Sample from Compressive Strength Test

Splitting Tensile Strength Test on the Concrete Cylinders

The splitting tensile test was conducted in accordance with the ASTM C496 standard to ascertain the tensile strength of the CHFRC and GFRC samples. The concrete cylinder samples, having undergone wet curing for a duration of 28 days, were demolded and positioned horizontally along the base plate of the UTM, as illustrated in **Figure 8**. Two flat strips of wood were positioned along the center of the sample to align symmetrically at the bottom and top contact points of the bottom and top bearing plates of the UTM, respectively, in such a way that an equilibrium position is established. Subsequently, the machine was activated, and an applied load rate of 0.3 to 0.6 MPa/Sec was applied at the point of failure (maximum shear load). The resulting readings were meticulously recorded, and the splitting tensile strength was calculated as outlined in the ASTM International (2004) standard.

$$T = \frac{2P}{\pi l d} \qquad (2)$$

where T = tensile strength (MPa), P = load at failure (N), l = length (mm) and d = diameter (mm)

Figure 5. Split Sample from the Splitting Tensile Strength Test

3. Discussion of Results

Effect of Cornhusk Fiber on 28th Day Compressive Strength

Subsequent to the completion of the 28-day curing period, **Figure 9** presents the computed compressive strengths of the cylinder samples fabricated from cornhusk fiber-reinforced concrete (CHFRC) and glass fiber-reinforced concrete (GFRC).It is evident that there exists a discernible negative correlation between the CHFRC samples' average compressive strength and the proportion of integrated fiber. This decline can be attributed to a weakened cement-aggregate bond as the amount of CHF increases (Erdem et al., 2011; Tang et al., 2023). Additionally, due to the varying lengths of the CHF, entanglement and agglomeration occur amongst longer fibers, weakening the cement aggregate bond and, consequently, compressive strength (W. Ahmad et al., 2020; Wang et al., 2019). Among the CHFRC variants, the 0.5% CHFRC demonstrated the strongest compressive strength, exhibiting a notable 12% enhancement over the baseline M25 concrete strength. However, it was observed that the 0.1% Glass Fiber Reinforced Concrete (GFRC) variant exhibited superior compressive strength compared to the target for plain M25 concrete, surpassing it by 36%. Furthermore, the 0.1% GFRC variant outperformed the 0.5% CHFRC by a margin of 21%. Conversely, the 1.0% CHF and 1.5% CHF samples demonstrated diminished compressive strength, exhibiting reductions of 10.9% and 14.6%, respectively, compared with plain concrete.

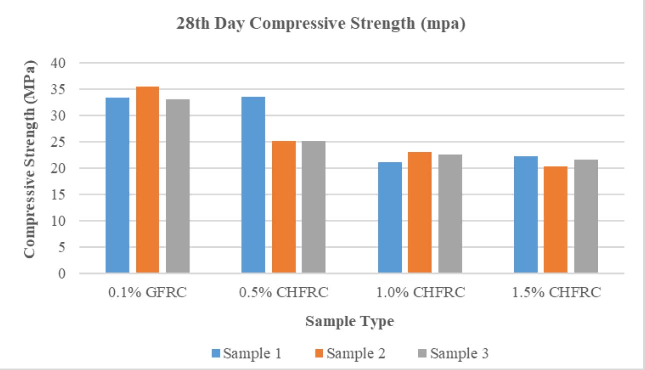

Figure 6. 28th Day Compressive Strength for the CHFRC and GFRC Cylinder Samples (MPa)

Effect of Age on Compressive Strength (CS) on CHFRC

To further analyze the strength behavior, compressive strength tests were conducted on the CHFRC and GFRC samples placed inside the laboratory and outside for 75 days and 150 days, as shown in **Table 5**. This was done to observe the CS progression with time in actual conditions. As expected, there was a general increase in strength for both the samples placed in the laboratory and those exposed to the environment as the age of the samples increased (Pourbaba et al., 2018; Seyam & Nemes, 2023). As illustrated in **Figure 10**, for the laboratory samples, the 0.1% GFRC exhibited the most significant increase in strength on both the 75th and the 150th day. This increase was 22% and 72%, respectively, compared to the strength on the 28th day. The 0.5% sample exhibited an increase of 15% on the 75th day and 95% on the 150th day, while the 1.5% CHFRC sample demonstrated the least increasing trend, with 9% and 37% increases on the 75th and 150th days, respectively.

Table 5. Average Compressive Strength for Lab Conditioned CHFRC and GFRC Cylinder Samples

Lab	**Average Compressive Strength (MPa)**		
Sample	**Day Zero**	**75th Day**	**150th Day**
0.5% CHF	27.93	28.82	48.86
1% CHF	22.26	21.87	41.34
1.5% CHF	21.35	23.29	29.32
0.1% GF	33.92	41.35	58.20

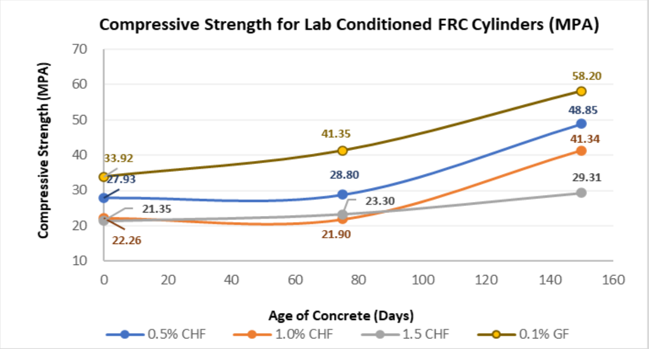

Figure 7. Average Compressive Strength vs. Age for Lab Conditioned CHFRC and GFRC Cylinder Samples

Consequently, for the samples exposed to the ambient environment, **Table 5** presents the mean compressive strength test results conducted for samples at 75 days and 150 days after the 28th day of the wet curing period. As illustrated in **Figure 11**, the 0.1% GFRC samples exhibited an enhancement in compressive strength of 27% and 80% on the 75th and 150th days, respectively, compared to the strength at the 28th day. Among the CHFRCs, the 0.5% CHFRC exhibited the most substantial increase in compressive strength, reaching 45% on the 75th day and 140% on the 150th day. In contrast, the 1.0% CHFRC demonstrated the least significant change in compressive strength, with an increase of 16% and 67%, respectively, on the 75th and 150th days.

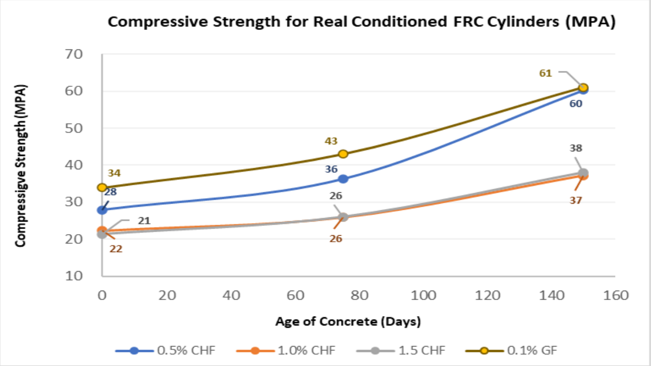

Figure 8. Average Compressive Strength vs. Age for Outside Conditioned CHFRC and GFRC Cylinder Samples

As illustrated in **Figures 12** and **13**, with increasing age, the 0.5% CHFRC exhibited the most significant increase in compressive strength compared to the 0.1% GFRC sample. This phenomenon can be attributed to the hydrophilic property of the CHF, which facilitates the retention of moisture over time, thereby promoting the internal hydration of concrete (Mishra, 2015). This, in turn, accelerates strength development in the concrete (Soroushian & Ravanbakhsh, 1999).

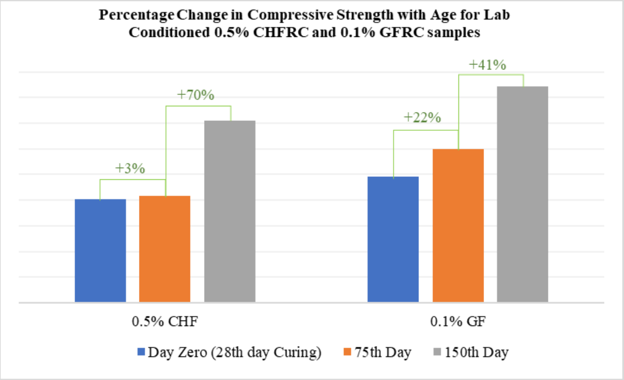

Figure 9. Percentage Change in Compressive Strength with Age for Lab Conditioned 0.5% CHFRC and 0.1% GFRC samples.

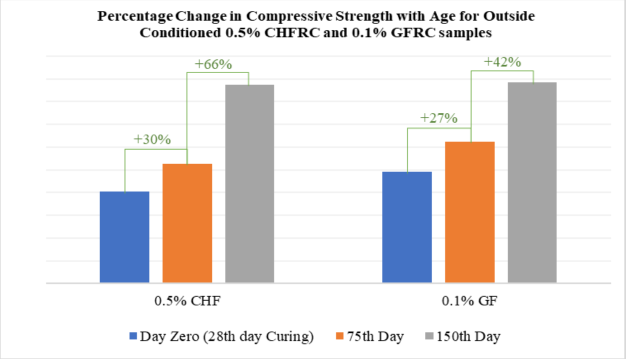

Figure 10. Percentage Change in Compressive Strength with Age for Outside Conditioned 0.5% CHFRC and 0.1% GFRC samples

Effect of Exposure Condition on Compressive Strength of CHFRC

A preliminary examination of the CS results for both the GFRC and the top-performing 0.5% CHFRC-aged concrete reveals that the samples exposed to external conditions exhibited higher values compared to the laboratory samples. This enhanced strength behavior can be attributed to the thermal cycling effect (Hakeem et al., 2023) that the samples experienced during the winter, spring, and summer seasons during the monitoring and exposure periods. Furthermore, the sustained curing and hydration processes triggered by exposure to moisture from rain and subsequent drying from heat have been linked to the enhancement of compressive strength properties (El-Zohairy et al., 2020). This is attributed to the intensified cement-water reaction, which leads to an increase in concrete hardness. As demonstrated in **Table 5** , the samples subjected to external conditions typically exhibit higher compressive strength values compared to those exposed to laboratory conditions.

Effect of Age and Exposure on Tensile Strength of CHFRC

As shown in **Table 6**, an increase in age was observed to correspond with a consistent increase in the lab-conditioned 0.1% GFRC, reaching 12% on the 75th day and less than 2% on the 150th day. Conversely, the samples exposed to external conditions exhibited a marginally more substantial enhancement in the splitting tensile strength of the 0.1% GFRC, with the 75th day reading measuring 3.51MPa and the 150th day reading reaching 3.74MPa. **Figures 14** and **15** demonstrate a similar trend for the 1.5% and 0.5% CHFRC samples placed in both laboratory and outdoor conditions.

Table 6. Average Splitting Tensile Strength for Lab Conditioned FRC Cylinder Samples

LAB	**Average Splitting Tensile Strength (MP)**		
Sample	**Day Zero (0)**	**75th Day**	**150th Day**
0.5% CHFRC	2.61	3.60	2.99
1% CHFRC	2.63	2.99	3.80
1.5% CHFRC	2.81	3.98	3.10
0.1% GFRC	3.30	3.68	3.70

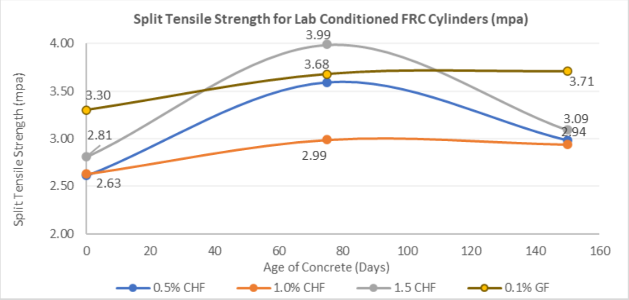

Figure 11. Average Splitting Tensile Strength vs. Age for Lab Conditioned FRC Cylinder Samples

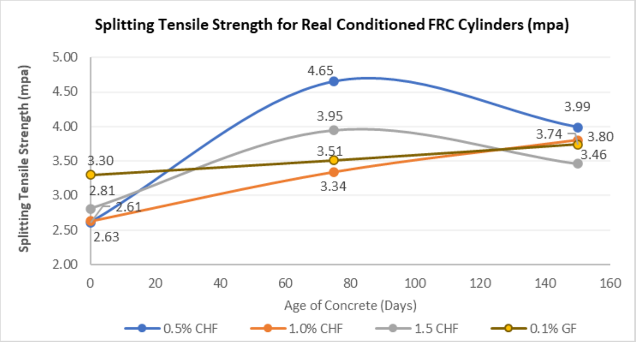

Figure 12. Average Splitting Tensile Strength vs. Age for Outside Conditioned FRC Cylinder Samples

As illustrated in **Figure 14**, the splitting tensile strengths exhibited a gradual increase up to the 75th day and subsequently underwent a decline of 22.2% and 15.5%, respectively, on the 150th day for the 1.5% and 0.5% CHFRC laboratory samples. In **Figure 15**, the tensile strengths of the samples collected on the 150th day exhibited a decline of 12.4% and 14.2% for the 1.5% and 0.5% CHFRC, respectively. Notwithstanding this decline, on the 150th day, the 0.5% CHFRC demonstrated superior performance in comparison to all the other samples, including the GFRC.

Effect of Cornhusk Fiber on the 28th Day Tensile Strength of Concrete

Tables 6 and **7** present the performance of the concrete composites under tension. The 0.1% GFRC samples exhibited the highest tensile strength, followed closely by the 1.5% CHFRC sample with a strength of 2.8MPa and the 0.5% sample demonstrating the poorest performance of 2.6MPa after the 28th day of the curing period. Despite the recorded low tensile strength values, this outcome indicates a positive correlation between the increase in fiber quantity and the tensile strength of the CHFRC samples (Syed et al., 2020). Upon conducting a post-failure pattern analysis, it was observed that the Glass Fiber-Reinforced Concrete (GFRC) sample displayed a split-through cut, signifying a limited ability to control post-crack behavior, as depicted in **Figure 16**. In contrast, the CHFRC sample exhibited a more favorable failure pattern, characterized by a well-contained and tightly held composite structure, as illustrated in **Figure 17**.

Table 7. Average Compressive Strength Test for Outside-conditioned CHFRC and GFRC Samples

Outside	Average Compressive Strength (MPa)		
Sample	Day Zero (28th)	75th Day	150th Day
0.5% CHF	27.93	36.31	60.34
1% CHF	22.26	25.90	37.22
1.5% CHF	21.35	26.00	38.00
0.1% GF	33.92	43.00	60.98

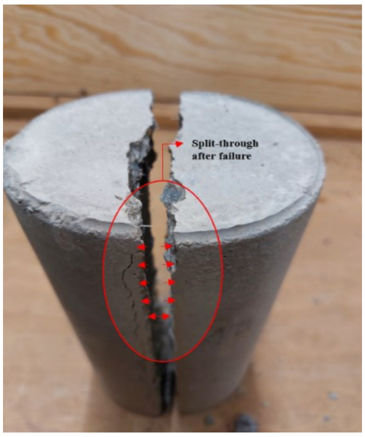

Figure 13. Failure Profile of the GFRC after the Splitting Tensile Strength Test

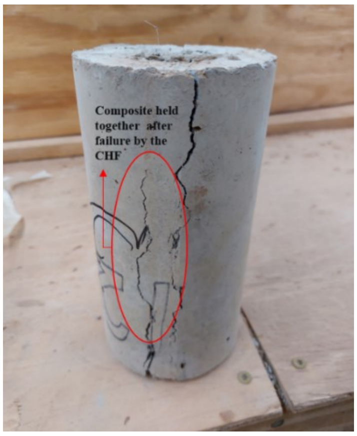

Figure 14. Failure Profile of the CHFRC after the Splitting Tensile Strength Test

4. Conclusions

In summary, the present study demonstrates that the incorporation of cornhusk fiber (CHF) into concrete can enhance specific mechanical properties.

Fiber Extraction: Among the various extraction methods evaluated, alkaline treatment emerged as the most efficient approach for extracting CHF, surpassing the effectiveness of water retting and boiling.

Compressive Strength:

- Among the concrete specimens tested, 0.1% glass fiber-reinforced concrete (GFRC) exhibited the highest overall strength.
- CHFRC demonstrated the most significant strength increase over time, with 0.5% CHFRC showing the greatest enhancement on the 28th day.
- The 0.5% CHFRC also exhibited faster strength gain than the 0.1% GFRC as the concrete aged, potentially attributable to CHF's capacity to retain water and enhance hydration.

Tensile Strength:

- At 28 days, 0.1% GFRC exhibited the highest tensile strength, with 1.5% CHFRC ranking second among the CHF samples.
- However, by 150 days, the tensile strength of all CHFRC samples decreased, with a 19% decline observed in laboratory conditions and a 13% decline in outdoor conditions.
- At this stage, the 0.5% CHFRC sample exhibited the highest tensile strength, surpassing all other samples, including the GFRC sample.

Optimal CHFRC Mix:

- The 0.5% CHFRC mix was identified as the most promising for compressive strength and long-term performance.
- While 1.5% CHFRC demonstrated the highest tensile strength at 28 days, 0.5% CHFRC exhibited superior outcomes after 150 days.

These findings underscore the promise of CHF as a sustainable material for enhancing concrete performance. This research serves as a preliminary study on the impact of cornhusk fiber on concrete durability. A more extensive investigation is warranted in the future to assess the effects of environmental conditions over an extended time period.

Availability of Data and Material

The datasets generated and/or analyzed during the present study are available from the corresponding author upon reasonable request. This includes all raw and processed data, as well as any materials used in the experiments. Researchers interested in accessing these resources for replication or further study are encouraged to contact the corresponding author for detailed information and arrangements.

Ethics approval and consent to participate

Hereby, We the authors assure that for the manuscript "Experimental Study on the Strength Behavior of Concrete Reinforced with Cornhusk Fiber" the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.

2) The paper is not currently being considered for publication elsewhere.

3) The paper reflects the authors' own research and analysis in a truthful and complete manner.

4) The paper properly credits the meaningful contributions of co-authors and co-researchers.

5) The results are appropriately placed in the context of prior and existing research.

6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.

7) All authors have been personally and actively involved in substantial work leading to the paper and will take public responsibility for its content.

We agree with the above statements and declare that this submission follows the policies of Solid-State Ionics as outlined in the Guide for Authors and in the Ethical Statement.

Authors' Contributions

Iselobhor Vincent Ikhine: As a graduate student, Iselobhor performed laboratory tests, conducted data collection, and played a key role in the experimental design for this case study. Firouz Rosti: Dr. Rosti served as the graduate investigator advisor, leading the project from its conceptualization to completion. He provided oversight and guidance throughout all phases of the research. Farid Hosseinpour: Farid contributed significantly to the project by assisting in data analysis and making substantial contributions to the writing of the final paper. Pavel Kraus: Pavel actively participated in all aspects of material collection, preparation, and laboratory tests, contributing essential expertise to these experimental processes. Vijaya Gopu: Dr. Gopu played a crucial role in the conceptualization of the project and the development of the research methodology, bringing valuable insights to the study design. Samuel Cooper: Dr. Cooper contributed to the project by participating in data analysis and providing a thorough final review of the paper, ensuring its academic rigor and quality.

Competing Interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Iselobhor Vincent Ikhine reports financial support was provided by Louisiana Transportation Research Center. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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