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Research Article

Analysis of the Effect of Water Hyacinth Waste Fiber Composition on the Compressive and Tensile Strength of 27 MPa Concrete

Ely Mulyati[1*], Krisnawati[1], and Achmad Syarifudin[1]

[1]Department of Civil Engineering, Faculty of Science Technology, Bina Darma University, Palembang, Indonesia

[*]Corresponding author: ely.mazpar@gmail.com
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Abstract

The utilization of natural fiber waste as a concrete additive has become an alternative approach to improve concrete performance while supporting sustainable construction. Water hyacinth (Eichhornia crassipes) is an abundant aquatic plant that poses environmental problems but contains cellulose fibers with the potential to enhance the mechanical properties of concrete. This study aimed to analyze the effect of water hyacinth fiber composition on the compressive strength and splitting tensile strength of concrete with a design strength of 27 MPa and to determine the optimum fiber content. An experimental method was employed using three concrete mixtures: normal concrete (0%), concrete with 0.025% water hyacinth fiber, and concrete with 0.050% water hyacinth fiber by cement weight. Twenty-seven cylindrical specimens (100 mm × 200 mm) were prepared for compressive strength tests at the ages of 7, 14, and 28 days, while nine cylindrical specimens (150 mm × 300 mm) were tested for splitting tensile strength at the age of 28 days. The results showed that the average 28-day compressive strengths were 26.8 MPa, 26.5 MPa, and 27.0 MPa for the 0%, 0.025%, and 0.050% mixtures, respectively. The average splitting tensile strengths were 3.16 MPa, 3.28 MPa, and 3.59 MPa. The addition of 0.050% water hyacinth fiber produced the best overall performance by maintaining the target compressive strength while increasing the splitting tensile strength. These findings indicate that water hyacinth fiber has considerable potential as an environmentally friendly natural additive for improving the mechanical performance of normal concrete.

Introduction

Concrete is the most widely used construction material in civil engineering because of its high compressive strength, durability, and adaptability to various structural applications (Indonesia, 2002; Mulyati et al., 2025; Nawy, 1985). However, concrete exhibits relatively low tensile strength and limited resistance to crack propagation, making it vulnerable to microcracking that may adversely affect structural durability and long-term service performance (Lumingkewas, 2023; Mulyati & Anggriani, 2022). To address these shortcomings, numerous researchers have investigated the incorporation of fibers into cementitious composites to improve crack resistance, ductility, toughness, and post-cracking behavior (Hasan et al., 2025; Indumathi et al., 2025; Jaberizadeh et al., 2023). In recent years, natural fibers and agricultural waste materials have attracted increasing attention as sustainable alternatives to synthetic fibers because they contribute to waste reduction and support environmentally friendly construction practices (Ahmed et al., 2023; Daisy Angel Priya et al., 2023).

One of the environmental concerns in Indonesia is the rapid proliferation of water hyacinth (Eichhornia crassipes), an invasive aquatic plant capable of covering large portions of rivers, lakes, and reservoirs (Ayyadurai et al., 2024; Dewi, 2012; Sugilar et al., n.d.). In the Musi River, Palembang, South Sumatra, excessive growth of water hyacinth has become a significant environmental concern. According to the Palembang Environmental Agency (2023), more than 40% of the river surface in several locations is covered by water hyacinth, resulting in obstruction of water flow, degradation of water quality, disruption of inland transportation, and reduced fisheries productivity. Although routine harvesting is conducted to control its spread, the collected biomass is generally discarded as organic waste without further utilization. This condition creates an opportunity to convert abundant local biomass into value-added materials for civil engineering applications.

The incorporation of natural fibers into concrete has become an important research topic because fibers can act as micro-reinforcement within the cementitious matrix. Natural fibers have been reported to enhance energy absorption capacity, delay crack propagation, and improve post-cracking behavior through a crack-bridging mechanism (Zaid et al., 2025). Similar approaches involving agricultural and natural fibers have also been investigated in the development of sustainable concrete. Nevertheless, the performance of natural fibers depends strongly on fiber geometry, dosage, surface condition, dispersion, and compatibility with the cementitious matrix. Therefore, the incorporation of natural fibers does not necessarily produce a proportional improvement in all mechanical properties of concrete.

Previous investigations have evaluated water hyacinth in different forms, including fibers, powder, and ash, and have produced considerably different mechanical responses. (Priyatno et al., 2017) reported reductions in compressive and tensile strengths when water hyacinth stem fibers were incorporated at dosages of 0.25–0.75%. (Zuraidah et al., 2022) similarly reported that increasing fiber content from 0.050% to 0.35% progressively reduced both compressive and splitting tensile strengths. Studies by (Abana et al., 2021; Affandy et al., 2018; Cahyono & Dhana, 2019; Hermawan et al., 2024) also indicated that incorporating water hyacinth fibers or powder could reduce compressive strength, particularly as the incorporated material increased. These findings suggest that excessive incorporation of water hyacinth-derived materials may adversely affect the integrity of the concrete matrix.

However, other studies have demonstrated different responses, indicating that the effect of water hyacinth on concrete cannot be generalized solely on the basis of its presence in the mixture. (Saluria, 2019) found that although water hyacinth fibers reduced compressive strength, their incorporation improved splitting tensile strength, indicating the potential contribution of fibers to crack resistance. (Nevometa et al., 2019) also reported improved flexural strength despite reductions in compressive and splitting tensile strengths. Meanwhile, (Junaidi et al., 2022) demonstrated that water hyacinth ash could increase compressive strength up to an optimum dosage before the strength subsequently declined. These contrasting results indicate that the mechanical performance of water hyacinth-based concrete is strongly influenced by the physical form of the material, fiber dimensions, dosage, mixture proportions, and the mechanical property being evaluated.

Despite these investigations, an important research gap remains regarding the use of water hyacinth as low-volume discrete fiber reinforcement in normal-strength concrete. Previous studies have commonly investigated water hyacinth-derived materials at contents ranging from approximately 0.10% to several percent, where reductions in compressive strength were frequently observed (Affandy et al., 2018; Cahyono & Dhana, 2019; Hermawan et al., 2024; Priyatno et al., 2017). Although (Zuraidah et al., 2022) evaluated a relatively low fiber dosage of 0.050%, the study still reported reductions in both compressive and splitting tensile strengths. This evidence demonstrates that simply reducing the fiber dosage does not automatically improve concrete performance and that the behavior of water hyacinth fibers at very low dosages requires further investigation under different mixture designs and fiber configurations. In particular, experimental evidence concerning fiber contents below 0.050%, such as 0.025% by cement weight, remains limited.

Another important gap concerns the simultaneous achievement of adequate compressive strength and improved tensile performance. Several previous studies have demonstrated that improvements in tensile or flexural behavior may be accompanied by reductions in compressive strength (Nevometa et al., 2019; Saluria, 2019). Consequently, the critical issue is not merely whether water hyacinth fiber can modify the mechanical properties of concrete, but whether an appropriately controlled low dosage can provide sufficient crack-bridging action without adversely affecting the integrity of the concrete matrix. Furthermore, limited experimental evidence is available regarding the behavior of locally sourced water hyacinth fibers in 27 MPa normal-strength concrete, particularly when compressive strength development and splitting tensile strength are evaluated within the same experimental program. Therefore, the fiber dosage capable of providing a balanced compressive–tensile response remains insufficiently established.

Based on these research gaps, this study aims to evaluate the influence of very low water hyacinth fiber contents on the compressive and splitting tensile strengths of concrete with a target compressive strength of 27 MPa and to identify the optimum fiber composition within the investigated range. Three concrete mixtures were prepared: normal concrete without fibers (0%), concrete containing 0.025% water hyacinth fibers, and concrete containing 0.050% fibers by cement weight. Compressive strength was evaluated at curing ages of 7, 14, and 28 days to examine strength development, while splitting tensile strength was evaluated at 28 days. The experimental procedures were conducted in accordance with the relevant Indonesian National Standards, including SNI 03-1972-1990, SNI 2491:2014, and SNI 03-2847-2002, to maintain consistency throughout the experimental program.

The novelty of this study lies not merely in the utilization of water hyacinth in concrete, but in the systematic evaluation of very low fiber dosages of 0.025% and 0.050% by cement weight to achieve a balanced compressive–tensile performance in 27 MPa concrete. The study specifically investigates whether a fiber content below or equal to 0.050% can maintain the target compressive strength while simultaneously improving splitting tensile resistance. In addition, locally sourced water hyacinth waste is processed into a controlled combination of 1.0 cm and 1.5 cm fibers, distinguishing the experimental configuration from studies using water hyacinth powder, ash, or higher fiber contents. By identifying the most effective fiber dosage within the investigated range, this study provides experimental evidence for the development of low-volume natural fiber-reinforced concrete while simultaneously offering a value-added utilization pathway for invasive water hyacinth biomass in sustainable civil engineering materials.

Research Method

Research Design and Study Area

This study employed an experimental laboratory method to investigate the effect of water hyacinth (Eichhornia crassipes) waste fiber composition on the compressive and splitting tensile strength of concrete with a design compressive strength of 27 MPa. The experimental program consisted of material characterization (Nasarudin et al., 2024), concrete mix design, specimen preparation, curing, and mechanical testing.

(a) (b)

Figure 1. (a) Location of Water Hyacinth (Eichhornia crassipes) Waste Collection, and (b) Civil Engineering Laboratory Testing Location (Source: Google Earth, adapted by the authors, 2025)

Water hyacinth was collected from the Musi River, Palembang, South Sumatra, which represents one of the largest sources of invasive aquatic biomass in the region. Laboratory processing of the fibers, concrete casting, curing, and mechanical testing were conducted at the Civil Engineering Laboratory, Universitas Bina Darma, Palembang.

Materials

The materials used in this research consisted of Ordinary Portland Cement (Type I), natural river sand as fine aggregate, crushed stone as coarse aggregate, clean mixing water, water hyacinth fibers, and a superplasticizer admixture. The water hyacinth stems were cleaned, sun-dried, and cut into two fiber lengths, namely 1.0 cm (40%) and 1.5 cm (60%), before being incorporated into the concrete mixture.

Figure 2. Water Hyacinth Fiber Segments (Source: Authors' documentation, 2025)

Prior to concrete production, the physical properties of the aggregates were evaluated, including particle size distribution, bulk density, specific gravity, water absorption, and mud content. In addition, the water hyacinth fibers were characterized through moisture content determination and dimensional uniformity to ensure consistency throughout the experimental program. All material characterization followed the relevant Indonesian National Standards (SNI).

Experimental Variables and Mix Proportions

The independent variable in this study was the percentage of water hyacinth fiber (WHF) incorporated into the concrete mixture, while the dependent variables were compressive strength and splitting tensile strength. Three fiber contents were investigated: 0% (normal concrete), 0.025%, and 0.050% by cement weight. For the compressive strength test, nine specimens were prepared for each mixture, resulting in a total of 27 cylindrical specimens. The percentage compositions of the constituent materials and the number of specimens used for compressive strength testing are presented in Table 1.

Table 1. Percentage Composition of Concrete Materials for Compressive Strength Testing

Mix Code	Concrete Constituent Materials (%)						Number of Specimens
	Coarse Aggregate	Fine Aggregate	Portland Cement	Water	Water Hyacinth Fiber	*Super Plasticizer*	
NC	43,35	29,06	18,97	8,62	0	0	9
WHF Concrete 0.025%	43,35	29,06	18,94	8,60	0,025	0,025	9
WHF Concrete 0.050%	43,35	29,06	18,92	8,57	0,050	0,050	9
Total number of specimens							27

For the splitting tensile strength test, three specimens were prepared for each mixture at the same fiber-content levels, resulting in a total of nine cylindrical specimens. The percentage compositions of the constituent materials and the number of specimens used for splitting tensile strength testing are summarized in Table 2.

Table 2. Percentage Composition of Concrete Materials for Splitting Tensile Strength Testing

Mix Code	Concrete Constituent Materials (%)						Number of Specimens
	Coarse Aggregate	Fine Aggregate	Portland Cement	Water	Water Hyacinth Fiber	*Super Plasticizer*	
NC	43,35	29,06	18,97	8,62	0	0	3
WHF Concrete 0.025%	43,35	29,06	18,94	8,60	0,025	0,025	3
WHF Concrete 0.050%	43,35	29,06	18,92	8,57	0,050	0,050	3
Total number of specimens							**9**

The concrete mix design was developed using the Indonesian concrete mix design method with a water–cement ratio of 0.46. As shown in Tables 1 and 2, the proportions of coarse and fine aggregates were maintained at 43.35% and 29.06%, respectively, whereas minor adjustments were made to the proportions of Portland cement and water to accommodate the addition of water hyacinth fiber and superplasticizer. The WHF and superplasticizer contents were increased according to the designated experimental variations. This mixture design enabled the mechanical performance of the three concrete mixtures to be compared under controlled experimental conditions.

Specimen Preparation

Concrete mixing was carried out using a laboratory concrete mixer following the sequence specified in SNI 2493:2011. Coarse aggregate, part of the mixing water, and superplasticizer were first introduced into the mixer, followed by fine aggregate, cement, and the remaining water. Water hyacinth fibers were subsequently added according to the designated fiber dosage. Mixing continued until a homogeneous mixture without segregation was obtained.

The workability of each mixture was evaluated using the slump test in accordance with SNI 03-1972-1990 before casting. Fresh concrete was then placed into cylindrical molds and compacted in three equal layers with 25 roddings per layer. Two specimen sizes were prepared :

1. 100 mm × 200 mm cylinders for compressive strength testing.
2. 150 mm × 300 mm cylinders for splitting tensile strength testing.

After casting, all specimens remained in their molds for 24 hours before demolding and subsequent curing.

Curing and Mechanical Testing

Following demolding, all specimens were cured by complete water immersion at room temperature until the scheduled testing ages. A total of 27 cylindrical specimens were prepared for compressive strength testing, consisting of three mixtures with nine specimens each. Compression tests were conducted at 7, 14, and 28 days using a Compression Testing Machine (CTM) following SNI 1974:2011.

In addition, nine cylindrical specimens were prepared for splitting tensile strength testing. The tests were performed at the age of 28 days according to SNI 03-2491-2002 using the indirect tensile loading method. The maximum applied load was recorded for each specimen and used to calculate the corresponding compressive and splitting tensile strengths.

Data Analysis

The experimental results were analyzed using a descriptive-comparative approach by comparing the mechanical properties of fiber-reinforced concrete with those of normal concrete. Average values of slump, compressive strength, and splitting tensile strength were calculated for each mixture.

The influence of fiber dosage on concrete performance was evaluated by examining the strength development at different curing ages, identifying the optimum fiber composition, and comparing the results with findings reported in previous studies. The analysis emphasized the effectiveness of low water hyacinth fiber contents in maintaining the target compressive strength while improving the splitting tensile strength of 27 MPa concrete.

Results and Discussion

Material Characteristics

The characteristics of the constituent materials were evaluated before concrete production to determine their suitability for the designed 27 MPa concrete. The results of the material characterization, including the fineness modulus, bulk density, water absorption, mud content, and moisture content of the water hyacinth fiber, are summarized in Table 3.

Table 3. Summary of Material Characteristics

Material parameter	Test result
Coarse aggregate fineness modulus	3.38
Coarse aggregate loose bulk density	1.348 g/cm³
Coarse aggregate compacted bulk density	1.571 g/cm³
Coarse aggregate water absorption	2.24%
Fine aggregate fineness modulus	2.35
Fine aggregate loose bulk density	1.258 g/cm³
Fine aggregate compacted bulk density	1.375 g/cm³
Fine aggregate water absorption	3.355%
Fine aggregate mud content	0.672%
Water hyacinth fiber moisture content	25.25%

As presented in Table 3, the coarse aggregate had a fineness modulus of 3.38, with loose and compacted bulk densities of 1.348 g/cm³ and 1.571 g/cm³, respectively. The water absorption of the coarse aggregate was 2.24%. The coarse aggregate had a maximum particle size of 20 mm, and the sieve analysis indicated that its particle-size distribution generally remained within the grading limits adopted in the mix design. These characteristics indicate that the coarse aggregate was suitable for use in the experimental concrete mixtures.

The fine aggregate had a fineness modulus of 2.35, with loose and compacted bulk densities of 1.258 g/cm³ and 1.375 g/cm³, respectively, as also summarized in Table 3. Its water absorption was 3.355%, while the measured mud content was 0.672%. The relatively low mud content indicated that the fine aggregate contained only a limited amount of fine impurities that could interfere with the bond between the aggregate and cement paste. Together with the coarse aggregate grading, these characteristics provided an appropriate aggregate system for the concrete mixtures investigated in this study.

The water hyacinth fibers were prepared using two fiber lengths, namely 1.0 cm and 1.5 cm, representing 40% and 60% of the fiber composition, respectively. As shown in Table 3, the moisture content of the prepared fiber was 25.25%. This result indicates that moisture condition was an important parameter in fiber preparation because variations in the moisture retained by the fibers could influence the amount of free water available in the fresh concrete. Therefore, consistent drying and moisture control were applied during fiber preparation to minimize variations among the experimental mixtures.

Overall, the characterization results presented in Table 3 provided the basis for evaluating the suitability and consistency of the constituent materials before concrete production. The aggregate characteristics were used in establishing the concrete mixture proportions, while the moisture condition and dimensions of the water hyacinth fibers were controlled to improve consistency among the normal concrete and fiber-reinforced concrete mixtures.

Fresh Concrete Workability

The slump values of normal concrete and water hyacinth fiber concrete are presented in Table 4. The results indicate a progressive decrease in slump with increasing water hyacinth fiber content. Normal concrete exhibited a slump of 10.0 cm, which decreased to 9.2 cm at a fiber content of 0.025% and further decreased to 8.6 cm at 0.050%. Compared with normal concrete, these values correspond to reductions of approximately 8.0% and 14.0%, respectively. Therefore, the incorporation of water hyacinth fiber reduced the workability of fresh concrete in a dosage-dependent manner.

The reduction in slump can be associated with the fibrous and porous characteristics of water hyacinth. The fibers may absorb part of the available mixing water while simultaneously increasing the internal friction and mechanical interlocking among the solid constituents. Furthermore, randomly distributed fibers can restrict the relative movement of aggregates and cement paste, resulting in a more cohesive and less flowable mixture. This effect became more pronounced as the fiber content increased from 0.025% to 0.050%.

Table 4. Slump Test Results

Concrete mixture	Fiber content	Slump value
Normal concrete	0%	10.0 cm
WHF concrete	0.025%	9.2 cm
WHF concrete	0.050%	8.6 cm

Despite the reduction in workability, all mixtures remained within the planned slump range of 7.5–15.0 cm. Therefore, the incorporation of up to 0.050% water hyacinth fiber did not reduce the workability beyond the acceptable range adopted in this study. The mixtures remained sufficiently workable for specimen casting and compaction under the laboratory conditions.

From an engineering perspective, the reduction in workability must be considered when higher fiber contents are used. Increasing the mixing water is not recommended because it may increase the effective water–cement ratio and reduce concrete strength. Workability should instead be controlled through fiber preconditioning, improved mixing procedures, or an appropriate dosage of superplasticizer.

Compressive Strength Development

The compressive strength development of normal concrete and water hyacinth fiber (WHF) concrete was evaluated at curing ages of 7, 14, and 28 days. The average compressive strength values for each mixture are summarized in Table 5, while their strength development with curing age is illustrated in Figure 3.

Table 5. Average Compressive Strength of Concrete

Concrete mixture	Fiber content	7 days	14 days	28 days
Normal concrete	0%	12,5 MPa	15,3 MPa	26,8 MPa
WHF concrete	0,025%	13,2 MPa	15,5 MPa	26,5 MPa
WHF concrete	0,050%	11,9 MPa	16,8 MPa	27,0 MPa

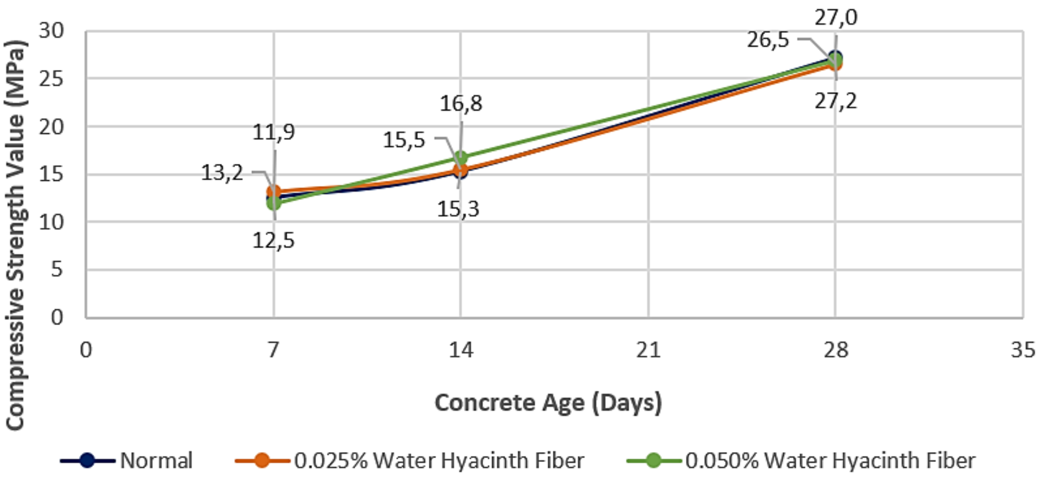

Figure 3. Comparison of the Compressive Strength Development of Normal Concrete and Water Hyacinth Fiber-Reinforced Concrete

All mixtures exhibited an increase in compressive strength with curing age. This development was primarily associated with the continued hydration of cement, which increased the density and strength of the cementitious matrix.

At 7 days, the concrete containing 0.025% fiber reached 13.2 MPa, representing an increase of approximately 5.6% compared with normal concrete. In contrast, the 0.050% mixture reached 11.9 MPa, approximately 4.8% lower than the normal concrete value. The lower early-age strength at the higher dosage suggests that the additional fiber temporarily interfered with compaction, hydration, or the uniform distribution of paste around the aggregate particles.

At 14 days, the average strengths of normal concrete, the 0.025% mixture, and the 0.050% mixture were 15.3, 15.5, and 16.8 MPa, respectively. The 0.050% mixture exhibited the highest value and was approximately 9.8% stronger than the normal concrete at the same age. This finding indicates that after sufficient curing, the interaction between the fiber, cement paste, and aggregate became more effective.

At 28 days, normal concrete achieved an average compressive strength of 26.8 MPa. The concrete containing 0.025% fiber reached 26.5 MPa, representing a slight reduction of approximately 1.12%. By contrast, the 0.050% mixture achieved 27.0 MPa, which was approximately 0.75% higher than the normal concrete and met the design strength of 27 MPa.

The differences among the 28-day compressive strengths were relatively small. This indicates that low dosages of water hyacinth fiber did not substantially alter the concrete's ability to resist compressive loads. The 0.025% fiber content slightly reduced the final compressive strength, possibly because the amount of fiber was insufficient to provide effective crack restraint but was still capable of generating small voids or weak interfaces. Conversely, the 0.050% dosage appears to have provided a more effective fiber distribution and crack-arresting mechanism without producing excessive agglomeration.

Table 6. Percentage Change in Compressive Strength Compared with Normal Concrete

WHF	7 Days	14 Days	28 Days
0.025%	+5.60%	+1.31%	−1.12%
0.050%	−4.80%	+9.80%	+0.75%

Water hyacinth fiber does not function as a primary load-bearing component under compression. Its principal contribution is to limit the initiation and propagation of microcracks. Under increasing compressive stress, microcracks develop within the cement paste and at the interfacial transition zone. Properly dispersed fibers can bridge these cracks and delay their coalescence into larger cracks. This mechanism explains why the 0.050% mixture maintained and slightly improved the 28-day compressive strength.

However, the limited increase in compressive strength also shows that natural fibers should not be expected to produce a major compressive-strength enhancement at very low dosages. Their greater benefit is generally associated with crack control, post-cracking behavior, and tensile resistance.

Splitting Tensile Strength

The average splitting tensile strength results at 28 days are shown in Table 7. The normal concrete produced an average splitting tensile strength of 3.16 MPa. Adding 0.025% water hyacinth fiber increased the value to 3.28 MPa, equivalent to an improvement of approximately 3.80%. The highest result, 3.59 MPa, was obtained at a fiber content of 0.050%, representing an increase of 0.43 MPa or approximately 13.61% relative to normal concrete. All measured splitting tensile strengths ranged from 2.43 to 4.05 MPa, corresponding to approximately 9–15% of the target compressive strength (27 MPa).

Table 7. Average Splitting Tensile Strength at 28 Days

Concrete mixture	Fiber content	Splitting tensile strength	Change from normal concrete
Normal concrete	0%	3.16 MPa	–
WHF concrete	0.025%	3.28 MPa	+3.80%
WHF concrete	0.050%	3.59 MPa	+13.61%

As shown in Figure 4, the splitting tensile strength generally increased with increasing water hyacinth fiber content. The average splitting tensile strength increased from 3.16 MPa for normal concrete to 3.28 MPa at 0.025% fiber content and reached the highest value of 3.59 MPa at 0.050% fiber content. This trend differs from the 28-day compressive-strength results, where the differences among the mixtures were relatively small. Therefore, within the investigated range, the addition of water hyacinth fiber had a more pronounced effect on splitting tensile strength than on compressive strength.

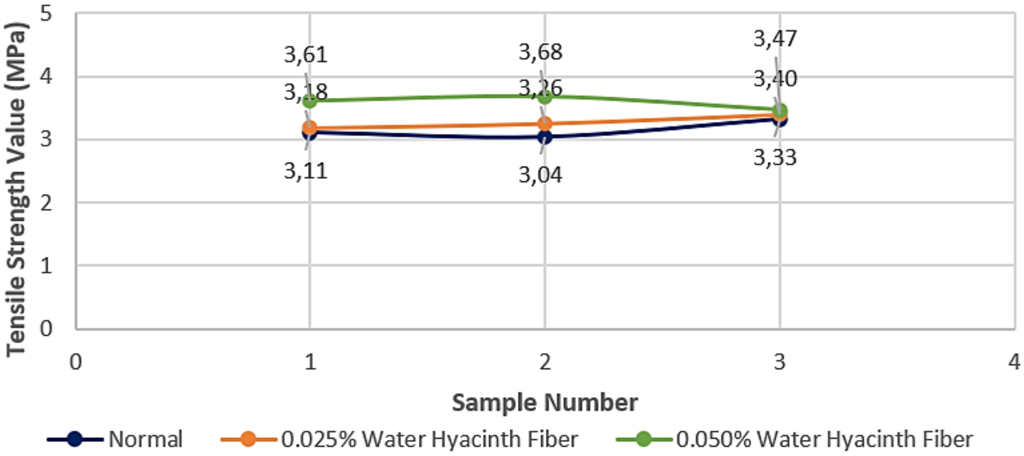

Figure 4. Comparison of the Compressive Strength Development of Normal Concrete and Water Hyacinth Fiber-Reinforced Concrete

Table 8. Ratio of Splitting Tensile to Compressive Strength

Concrete mixture	Compressive strength	Splitting tensile strength	Tensile-to-compressive ratio
Normal concrete	26.8 MPa	3.16 MPa	11.79%
WHF concrete 0.025%	26.5 MPa	3.28 MPa	12.38%
WHF concrete 0.050%	27.0 MPa	3.59 MPa	13.30%

As presented in Table 8, the tensile-to-compressive strength ratio increased from 11.79% for normal concrete to 12.38% and 13.30% for concrete containing 0.025% and 0.050% water hyacinth fiber, respectively. This increase indicates that the addition of water hyacinth fiber had a more pronounced effect on splitting tensile strength than on compressive strength within the investigated range. The improvement in splitting tensile strength may theoretically be associated with the role of fibers as micro-reinforcement within the cementitious matrix. Fibers distributed across potential crack planes may contribute to stress transfer and restrict crack opening through a crack-bridging mechanism. However, crack propagation, post-cracking behavior, and fracture energy were not directly evaluated in this study. Therefore, the crack-bridging mechanism is presented as a theoretical interpretation of the observed increase in splitting tensile strength rather than as a directly measured mechanism.

Overall Effect of Water Hyacinth Fiber

The overall findings demonstrate that increasing the water hyacinth fiber content produced two contrasting effects. First, it reduced fresh concrete workability because the fiber absorbed water and restricted internal movement. Second, it improved splitting tensile strength and maintained the compressive strength near the target value.

At a fiber content of 0.025%, the concrete exhibited better early-age compressive strength but a slightly lower 28-day compressive strength than normal concrete. Although the reduction was small, this result indicates that the interaction between natural fibers and concrete is not always linear. Fiber dispersion, moisture condition, void formation, and interfacial adhesion can all influence the measured performance.

The 0.050% mixture produced the lowest slump but achieved the highest 14-day compressive strength, the highest 28-day compressive strength, and the highest splitting tensile strength among the investigated mixtures. This indicates that a fiber content of 0.050% provided the most favorable balance between workability and mechanical performance within the investigated range. The higher splitting tensile strength suggests an improved ability of the concrete to resist indirect tensile stresses. Nevertheless, this result should not be interpreted as direct evidence of improved crack resistance or crack-bridging behavior, as crack propagation and post-cracking response were not directly measured in this study. Further fracture-based testing is therefore required to verify the mechanisms responsible for the observed tensile-strength improvement.

The findings also show that the main engineering advantage of water hyacinth fiber lies in improving resistance to tensile cracking rather than substantially increasing compressive strength. This characteristic is relevant for concrete elements subjected to shrinkage, temperature effects, impact, or indirect tensile stresses. The use of water hyacinth waste may therefore provide both mechanical and environmental benefits by converting invasive aquatic biomass into a supplementary material for concrete.

Nevertheless, the relatively high moisture content and reduction in slump indicate that fiber preparation is critical. Inconsistent drying or fiber distribution may modify the effective water–cement ratio and generate variability in strength. For practical application, standardized drying, dimensional control, uniform mixing, and workability adjustment are required.

Optimum Fiber Composition

Based on the combined evaluation of compressive strength, splitting tensile strength, and fresh concrete workability, the 0.050% water hyacinth fiber content by cement weight provided the most favorable overall performance among the mixtures investigated in this study. At this fiber dosage, the concrete exhibited a slump value of 8.6 cm, which remained within the planned workability range of 7.5–15.0 cm, while achieving a 28-day compressive strength of 27.0 MPa and a splitting tensile strength of 3.59 MPa. The corresponding splitting tensile-to-compressive strength ratio was 13.30%.

The 0.050% fiber content was identified as the best-performing composition because it provided the most favorable balance among the three performance criteria evaluated in this study. Compared with normal concrete, the 0.050% mixture increased the 28-day compressive strength from 26.8 MPa to 27.0 MPa and increased the splitting tensile strength from 3.16 MPa to 3.59 MPa, corresponding to improvements of approximately 0.75% and 13.61%, respectively. In comparison, the 0.025% mixture produced a slightly lower 28-day compressive strength of 26.5 MPa and a splitting tensile strength of 3.28 MPa. Thus, among the tested mixtures, only the 0.050% mixture simultaneously achieved the target compressive strength of 27 MPa and the highest splitting tensile strength. Although its slump decreased by approximately 14.0% relative to normal concrete, the measured value of 8.6 cm remained within the planned workability range, indicating that the improvement in mechanical performance was achieved without reducing workability below the criterion adopted in this study.

Therefore, the selection of 0.050% as the optimum fiber content was based not solely on its highest splitting tensile strength, but on its combined ability to achieve the target 28-day compressive strength, provide the highest splitting tensile performance, and maintain acceptable fresh concrete workability. Within the investigated fiber-content range of 0–0.050%, this dosage consequently provided the most balanced overall performance. However, the designation of 0.050% as the optimum should be interpreted as the optimum within the range investigated in this study, rather than as a universal optimum dosage, because fiber contents above 0.050% were not evaluated.

Conclusion

This study demonstrated that variations in water hyacinth waste fiber content influenced the compressive and splitting tensile strengths of 27 MPa concrete. Regarding the first research objective, the addition of water hyacinth fiber produced different effects on the two mechanical properties. The 28-day compressive strength of normal concrete was 26.8 MPa, while the mixtures containing 0.025% and 0.050% fiber achieved 26.5 MPa and 27.0 MPa, respectively. These results indicate that the incorporation of water hyacinth fiber within the investigated range caused only relatively small changes in the 28-day compressive strength. In contrast, the splitting tensile strength increased from 3.16 MPa for normal concrete to 3.28 MPa at 0.025% fiber content and 3.59 MPa at 0.050% fiber content. Thus, within the investigated range, increasing the water hyacinth fiber content had a more pronounced effect on splitting tensile strength than on compressive strength.

Regarding the second research objective, the 0.050% water hyacinth fiber content by cement weight provided the most favorable overall performance among the investigated mixtures. At this dosage, the concrete achieved a 28-day compressive strength of 27.0 MPa, corresponding to the target compressive strength, and the highest splitting tensile strength of 3.59 MPa, equivalent to approximately 13.30% of its compressive strength. Although this mixture produced the lowest slump value of 8.6 cm, the value remained within the planned workability range of 7.5–15.0 cm. Therefore, 0.050% can be identified as the optimum fiber content within the investigated range of 0–0.050%, as it provided the most favorable combined performance in terms of compressive strength, splitting tensile strength, and workability.

The findings indicate that very low dosages of water hyacinth waste fiber have potential as a natural additive for 27 MPa concrete, particularly for improving splitting tensile performance while maintaining the target compressive strength. Furthermore, the utilization of water hyacinth waste in concrete may provide a potential value-added pathway for the utilization of invasive aquatic biomass and may contribute to waste-reduction efforts and the development of sustainable construction practices. However, the environmental sustainability of water hyacinth fiber-reinforced concrete was not directly evaluated in this study. Therefore, no definitive conclusions can be drawn regarding its life-cycle environmental performance, carbon emissions, economic feasibility, or overall environmental impact.

The optimum dosage identified in this study is also limited to the investigated fiber contents, fiber-length combination, constituent materials, and curing conditions. Further studies should evaluate intermediate and higher fiber dosages, different fiber dimensions and treatments, durability characteristics, and direct fracture or post-cracking behavior. In addition, life-cycle assessment (LCA), carbon-emission analysis, cost analysis, and environmental impact assessment are recommended to quantitatively determine whether the utilization of water hyacinth waste fiber in concrete can provide measurable environmental and economic benefits and support its broader application in sustainable construction.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The datasets generated during and/ or analyzedduring the current study are available from the corresponding author on reasonable request.

Use of Generative AI

No generative AI was used.

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