Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 02 February-2026, Page No.-9050-9055

DOI: 10.47191/etj/v11i02.30, I.F. – 8.482

Mechanical Performance of Concrete Reinforced with Hybrid Natural Plant Fibers

CABANESAS, Amor Judith A.

Instructor, Nueva Ecija University of Science and Technology, Sumacab Este, Cabanatuan City, Nueva Ecija, Philippines

ABSTRACT: The increasing demand for sustainable construction materials has encouraged the exploration of natural fibers as alternative reinforcement in concrete. This study investigates the mechanical performance of concrete reinforced with hybrid natural fibers derived from *Sansevieria trifasciata* (Snake Plant) and *Ficus elastica* (Rubber Tree). Concrete specimens were prepared with fiber contents of 0%, 0.25%, 0.375%, and 0.5% by volume and cured for 14 days under controlled conditions. The compressive and flexural strengths were determined using standard testing procedures, and the results were analysed using descriptive statistics and One-Way Analysis of Variance (ANOVA). Results showed that the addition of hybrid natural fibers significantly affected the compressive strength of concrete ($F = 23.56$, $p = 0.00025$), with strength decreasing as fiber content increased. The control specimen (0% fiber) exhibited the highest compressive strength (18.41 MPa), while the 0.5% fiber content yielded the lowest mean compressive strength (7.39 MPa) and the highest variability (CV ≈ 38.97%). In contrast, flexural strength showed no statistically significant difference among the groups ($F = 0.44$, $p = 0.73$), indicating that fiber incorporation did not substantially enhance bending performance at 14 days of curing. Overall, the findings suggest that while hybrid Snake Plant and Rubber Tree fibers may contribute to crack-bridging potential, their inclusion at the tested proportions does not improve early-age compressive strength and may reduce mechanical consistency at higher fiber contents. Further studies are recommended to optimize fiber treatment, proportioning, and curing duration to improve performance outcomes.

KEYWORDS: Hybrid Natural Plant Fibers, Sansevieria trifasciata (Snake Plant), Ficus elastica (Rubber Tree), Compressive Strength, Flexural Strength, Sustainability, Concrete Technology

I. INTRODUCTION

Concrete remains the dominant construction material due to its availability, durability, and high compressive strength; however, its low tensile and flexural capacity makes it prone to cracking and brittle failure. To overcome these limitations, fiber reinforcement has been widely investigated as a means of improving crack resistance, toughness, and post-cracking behavior of concrete (Ahmad et al., 2022; Okeola et al., 2018; Wang et al., 2022). Among reinforcement options, natural plant fibers have gained attention as sustainable and cost-effective alternatives to conventional synthetic and steel fibers.

Natural fibers are valued for their renewability, biodegradability, and lower environmental impact, while also contributing to improvements in compressive strength, flexural strength, and crack control in cementitious composites (Broeren et al., 2017; Ren et al., 2021; Sabarish et al., 2019). In the Philippines, Snake Plant (Sansevieria trifasciata) and Rubber Tree (Ficus elastica) are abundant yet underutilized fiber sources. Previous studies have demonstrated the effectiveness of individual plant fibers in enhancing the mechanical performance of concrete and concrete hollow blocks (Angeles et al., 2019; Elegores et al., 2019; Sarabia et al., 2019).

Despite these advancements, limited research has examined the hybrid incorporation of Snake Plant and Rubber Tree fibers in concrete, particularly regarding early-age compressive and flexural behavior. This study investigates the mechanical performance of concrete incorporating varying proportions of these hybrid natural fibers to evaluate their potential as sustainable reinforcement materials.

This research supports Sustainable Development Goal 9 by promoting innovative construction materials and Sustainable Development Goal 12 by encouraging the utilization of locally available plant-based resources in infrastructure development.

A. General Objective

To investigate the potential of hybrid natural fibers derived from Sansevieria trifasciata (Snake Plant) and Ficus elastica (Rubber Tree) as sustainable reinforcement materials in concrete by evaluating their effect on the 14-day compressive and flexural strength at varying fiber contents through experimental testing and statistical analysis.

B. Specific Objectives

1. To prepare concrete specimens incorporating hybrid natural fibers at fiber contents of 0%, 0.25%,

0.375%, and 0.5% by volume and cure them under controlled conditions for 14 days.

2. To determine the 14-day compressive and flexural strength of plain and hybrid fiber-reinforced concrete specimens using standard compression and flexural testing procedures
3. To compare the compressive and flexural strength performance of fiber-reinforced concrete with that of plain concrete at different fiber contents.
4. To evaluate whether significant differences exist among the different fiber content groups using descriptive statistics (mean, standard deviation, and percentage variation) and One-Way Analysis of Variance (ANOVA).
5. To identify the fiber content, if any, that provides improved mechanical performance at 14 days of curing.

II. METHODOLOGY

This study employed an experimental research design to evaluate the mechanical performance of concrete reinforced with hybrid natural fibers derived from Sansevieria trifasciata (Snake Plant) and Ficus elastica (Rubber Tree). The independent variable was the fiber content, while the dependent variables were the 14-day compressive and flexural strengths of concrete. Mechanical testing was conducted at an accredited Construction Materials Testing Laboratory in Cabanatuan City. Fiber materials were collected from selected areas in Nueva Ecija, specifically Cabanatuan City and Talavera.

Snake plant fibers were extracted from the leaves using the water retting method, while rubber tree fibers were obtained from the adventitious roots of the Ficus elastica through decortication. The fibers were cleaned, air-dried, and cut to uniform lengths of 50–60 mm prior to mixing. Concrete specimens were prepared with fiber contents of 0% (control), 0.25%, 0.375%, and 0.5% by volume. The mass of fiber incorporated in each mixture was calculated based on the volume of concrete and its unit weight, and standard mixing procedures were followed to ensure uniform distribution of fibers.

Figure 1. Snake Plant (Left) and Rubber Tree (Right) Fibers

Figure 2. Incorporation of Fiber to Concrete

For each fiber variation, cylindrical specimens measuring 150 mm in diameter and 300 mm in height were prepared for compressive strength testing, while beam specimens measuring 150 mm × 150 mm × 530 mm were prepared for flexural testing. All specimens were demolded after 24 hours and cured in water for 14 days prior to testing. Compressive strength was determined using a Universal Testing Machine under axial loading until failure, whereas flexural strength was measured using a third-point loading method.

Figure 3. Laboratory testing of concrete specimen under axial compression and flexural strength.

Data were analyzed using descriptive statistics, including mean, standard deviation, and coefficient of variation, to summarize the mechanical performance of each fiber group. One-Way Analysis of Variance (ANOVA) at a 0.05 significance level was conducted to determine whether significant differences existed among the different fiber content groups. To ensure reliability, each test was performed on three replicates per fiber content under controlled laboratory conditions.

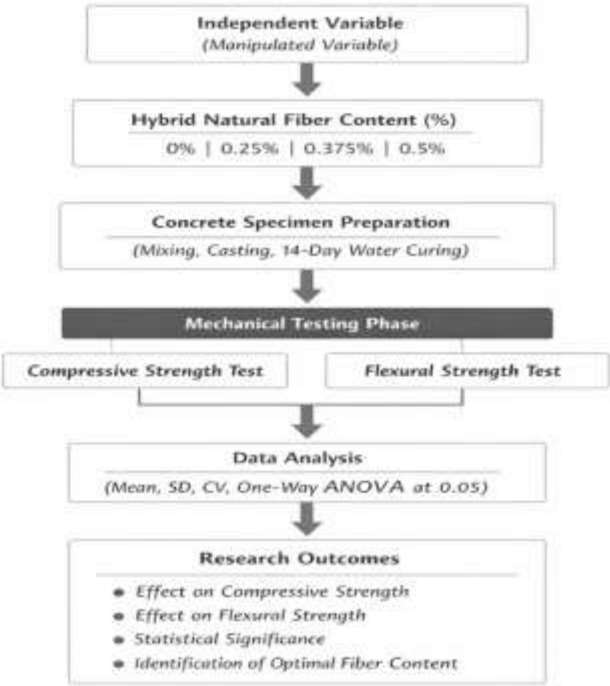

Figure 4. Conceptual Framework

III. RESULTS AND DISCUSSION

Compressive strength is highly dependent on concrete density, compaction, and internal matrix uniformity. The introduction of hybrid natural fibers appears to have altered these factors, resulting in decreased strength and increased variability at higher fiber contents. The compressive and flexural strength results obtained from the experimental testing are presented below.

Table 1. Individual Compressive and Flexural Strength Results

Fiber Content(%)	Sample	Compressive Strength(MPa)	Flexural Strength(MPa)
0 (Pure Concrete)	1	18.41	2.75
	2	18.41	2.75
	3	18.41	2.75
0.25	1	10.76	1.79
	2	13.61	3.35
	3	11.95	2.37
0.375	1	11.43	2.15
	2	10.57	2.47
	3	10.00	2.55
0.5	1	4.95	2.49
	2	6.66	2.99
	3	10.57	2.57

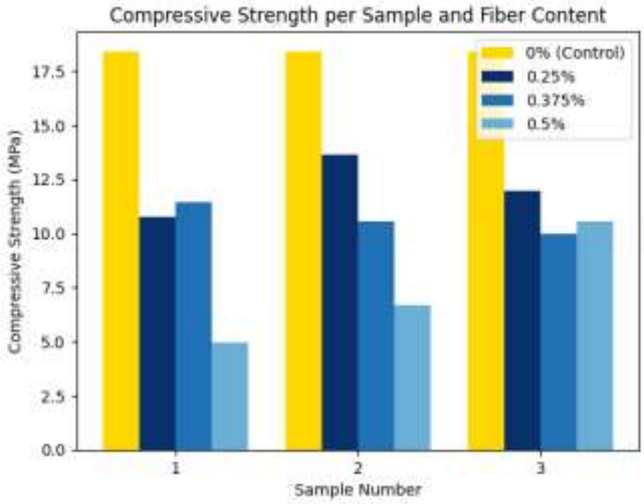

Figure 5. Comparison of compressive strength values for plain and hybrid natural fiber–reinforced concrete at different fiber volume fractions.

Compressive strength exhibited a clear declining trend with increasing fiber content. Moderate reductions were observed at lower fiber dosages, while a substantial decrease and high variability occurred at the highest fiber content. This suggests that excessive fiber addition disrupts the cement matrix, likely due to fiber clustering, increased void formation, and reduced bonding efficiency between the fibers and the cement paste. Such effects limit effective stress transfer and reduce load-carrying capacity, especially at early curing age.

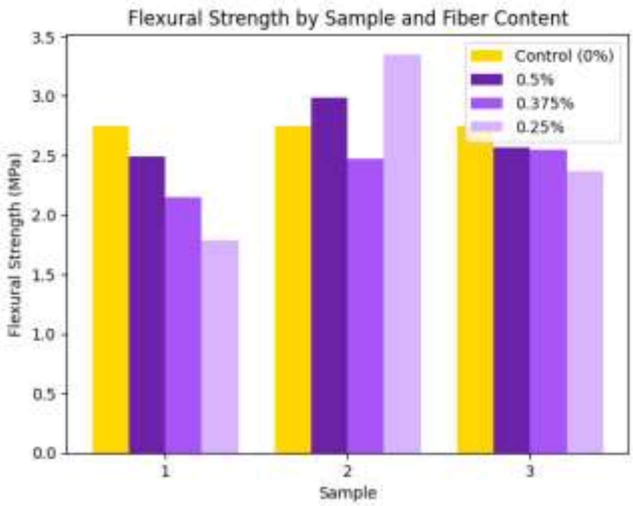

Figure 6. Comparison of flexural strength values for plain and hybrid natural fiber–reinforced concrete at different fiber volume fractions.

Flexural strength, however, remained relatively stable across all mixtures. Although some dispersion was noted at lower fiber content, the overall flexural performance of fiber-reinforced specimens was comparable to that of the control mixture. Statistical evaluation confirmed that the observed differences in flexural strength were not significant, indicating that the hybrid fibers, at the proportions tested, did not substantially enhance bending resistance.

Table 2. Statistical Summary of 14-Day Compressive and Flexural Strengths of Hybrid Natural Fiber–Reinforced Concrete

Fiber Content (%)	Compressive Strength (MPa) Mean ± SD	CV (%)	Flexural Strength (MPa) Mean ± SD	CV (%)
0 (Pure)	18.41 ± 0.00	0.00	2.75 ± 0.00	0.00
0.25	12.11 ± 1.43	11.82	2.50 ± 0.79	31.50
0.375	10.67 ± 0.72	6.75	2.39 ± 0.21	8.86
0.5	7.39 ± 2.88	38.97	2.68 ± 0.27	10.01

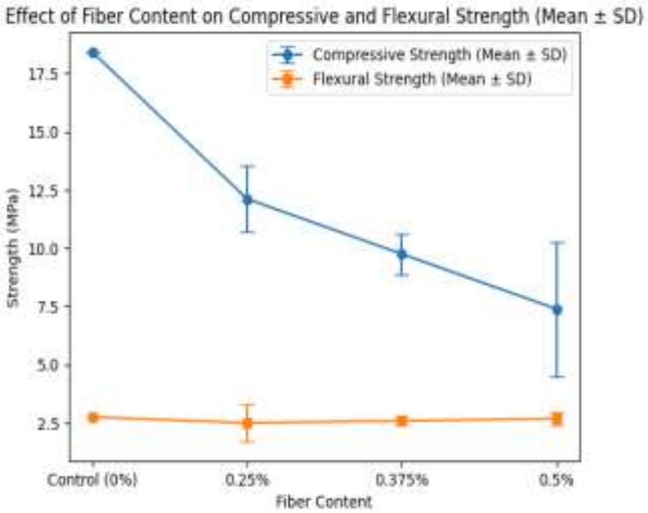

Figure 7. Mean Compressive and Flexural Strengths of Concrete at Different Fiber Contents with Standard Deviation

At 0.25% fiber content, the mean compressive strength decreased to 12.11 MPa with moderate variability (CV = 11.82%). Further reduction was observed at 0.375% fiber content, with a mean of 10.67 MPa and lower variability (CV = 6.75%), indicating more consistent behavior. The lowest compressive strength occurred at 0.5% fiber content (7.39 MPa) with high variability (CV = 38.97%), suggesting poor fiber dispersion and increased void formation.

Flexural strength showed minimal variation across mixtures. The control specimen recorded 2.75 MPa, while fiber-reinforced specimens exhibited comparable values ranging from 2.39 MPa to 2.68 MPa. Except for higher variability at 0.25% fiber content (CV = 31.50%), flexural behavior remained relatively stable despite changes in fiber proportion.

Table 3. Summary of One-Way ANOVA for Mechanical Properties of Hybrid Natural Fiber–Reinforced Concrete

Property	F-value	p-value	Interpretation
Compressive Strength	23.56	0.00025	Significant ($p < 0.05$)
Flexural Strength	0.44	0.73	Not Significant ($p > 0.05$)

One-way ANOVA results showed that fiber content had a statistically significant effect on compressive strength ($F = 23.56$, $p = 0.00025 < 0.05$). In contrast, flexural strength was not significantly affected by fiber addition ($F = 0.44$, $p = 0.73 > 0.05$), indicating no meaningful difference among the mixtures.

Statistical analysis demonstrated that fiber content exerted a significant influence on compressive strength, whereas its effect on flexural strength was statistically insignificant. The reduction in compressive strength at higher fiber dosages may be associated with decreased matrix density, increased void formation, and potential fiber agglomeration, which collectively disrupt stress transfer within the concrete matrix. Although hybrid natural fibers may contribute to crack-bridging mechanisms under flexural loading, their untreated incorporation did not produce measurable improvements in flexural capacity. The observed variability among fiber-reinforced mixes further suggests reduced homogeneity as fiber content increased, indicating that fiber–matrix interaction and dispersion play critical roles in mechanical performance.

CONCLUSIONS

This study evaluated the feasibility of hybrid natural fibers derived from *Sansevieria trifasciata* (Snake Plant) and *Ficus elastica* (Rubber Tree) as sustainable reinforcement materials in concrete by examining their influence on 14-day compressive and flexural strength at varying fiber contents. Concrete specimens containing 0%, 0.25%, 0.375%, and 0.5% hybrid fiber content were successfully prepared and tested under controlled curing conditions. The experimental results demonstrated that fiber incorporation significantly influenced compressive strength but did not significantly affect flexural strength at 14 days.

Compressive strength decreased progressively with increasing fiber content. Statistical analysis confirmed that these reductions were significant, indicating that hybrid fiber inclusion at the tested proportions adversely affected early-age load-bearing capacity. The highest fiber dosage produced both the lowest compressive strength and the greatest variability, suggesting reduced material homogeneity and weakened matrix integrity at higher fiber volumes.

In contrast, flexural strength values of fiber-reinforced concrete remained comparable to those of plain concrete, and no statistically significant differences were detected among fiber content groups. This indicates that, within the investigated range, hybrid fibers did not provide measurable enhancement in bending resistance at early curing age.

No fiber content demonstrated improved overall mechanical performance relative to plain concrete at 14 days. While hybrid fibers may contribute to crack-bridging mechanisms, their reinforcing potential was not realized under the tested conditions.

Overall, the findings establish that untreated hybrid Snake Plant and Rubber Tree fibers, when incorporated at low volume fractions, do not enhance early mechanical strength and may compromise compressive performance.

Nevertheless, the study provides important experimental evidence supporting the continued investigation of locally sourced plant-based fibers as sustainable construction materials. Optimization of fiber treatment, dispersion methods, and curing duration is recommended to improve fiber–matrix interaction and unlock the structural potential of hybrid natural fiber-reinforced concrete.

These results contribute to the advancement of sustainable material development by clarifying the performance limitations and future research directions for hybrid plant fiber reinforcement in cement-based composites.

ACKNOWLEDGMENT

The researcher sincerely expresses her gratitude to everyone who contributed to the completion of this study. She deeply appreciates the unwavering support of her family and extends heartfelt thanks to Almighty God for the strength, wisdom, and guidance throughout this research journey.

REFERENCES

1. Abass, O., Okeola, A., Abuodha, S., & Mwero, J. (2018). The effect of specimen shape on the mechanical properties of sisal fiber-reinforced concrete. *The Open Civil Engineering Journal, 12*, 368–382. https://doi.org/10.2174/1874149501812010368
2. Ahmad, J., Majdi, A., Deifalla, A. F., Ben Kahla, N., & El-Shorbagy, M. A. (2022). Concrete reinforced with sisal fibers: Overview of mechanical and physical properties. *Crystals, 12*(7), 952. https://doi.org/10.3390/cryst12070952
3. Angeles, J. M. I., Aquillano, M. A. S., & Diosomito, A. D. (2019). Screening of selected plant fibers as reinforcement material for concrete hollow blocks. *Ascendens Asia Journal of Multidisciplinary Research Abstracts*.
4. Baniel, M. O. Q., & Estores, G. (2022). Prediction of direct tensile strength of bamboo fiber reinforced concrete using artificial neural network. *Key Engineering Materials*.
5. Broeren, M., Dellaert, S. N. C., Cok, B., Patel, M. K., Worrell, E., & Shen, L. (2017). Life cycle assessment of sisal fibre: Exploring how local practices influence environmental performance. *Journal of Cleaner Production, 149*, 818–827. https://doi.org/10.1016/j.jclepro.2017.02.073
6. Elegores, K. F., Mendoza, L. D., & Dulitin, M. (2019). Reinforcement of concrete hollow blocks using rubber tree (Ficus elastica) fiber. *Ascendens Asia Journal of Multidisciplinary Research Abstracts*.
7. Geremew, A., De Winne, K., Demissie, A., & De Backer, H. (2021). Treatment of natural fiber for application in concrete pavement. *Advances in Civil Engineering*.
8. Iniya, I., & Nirmalkumar, N. (2021). A review on fiber reinforced concrete using sisal fiber. *IOP Conference Series Materials Science and Engineering*.
9. Khan, M., et al. (2020). Efficiency of silica-fume content in natural fiber reinforced concrete. *Construction and Building Materials*.
10. Okeola, A. A., Abuodha, S. O., & Mwero, J. (2018). Experimental investigation of the physical and mechanical properties of sisal fiber-reinforced concrete. *Fibers, 6*(3), 53. https://doi.org/10.3390/fib6030053
11. Ren, G., Yao, B., Ren, M., & Gao, X. (2021). Utilization of natural sisal fibers to manufacture eco-friendly ultra-high performance concrete. *Journal of Cleaner Production, 332*, 130105. https://doi.org/10.1016/j.jclepro.2021.130105
12. Sabarish, K. V., et al. (2019). Experimental investigation on properties of sisal fiber used in concrete. *Materials Today Proceedings*.
13. Sarabia, A. S., Ramos, J., & Diquit, K. (2019). Snake plant (Sansevieria trifasciata) and abaca fiber as compressive enhancer for concrete hollow blocks. *Ascendens Asia Journal of Multidisciplinary Research Abstracts*.
14. Sivakumar, A., & Santhanam, M. (2017). A quantitative study on plastic shrinkage cracking in hybrid fibre reinforced concrete. *Cement and Concrete Composites*.
15. Thomas, B. C., & Jose, Y. S. (2019). Impact of sisal fiber reinforced concrete and its performance analysis: A review. *Evolutionary Intelligence*.
16. United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. United Nations. https://sdgs.un.org/2030agenda
17. Van Ackeren, J., et al. (2021). Impact study of textile reinforced cementitious materials: Test method and preliminary results. *Brittle Matrix Composites*.
18. Wang, S., Zhu, H., Liu, F., Sheikh, M. N., Wang, B., & Yang, L. (2022). Effects of steel fibers on flexural toughness of ultra-high-performance concrete. *Case*

Studies in Construction Materials, 17, e01170. https://doi.org/10.1016/j.cscm.2022.e01170

19. Widyasanti, A., Napitupulu, F., & Thoriq, A. (2020). Physical and mechanical properties of natural fiber from Sansevieria trifasciata. *IOP Conference Series Earth and Environmental Science*.