EXPERIMENTAL ANALYSIS OF THE EFFECTIVENESS OF BANANA FIBER REINFORCEMENT IN CONCRETE

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ABSTRACT

This study investigates the potential use of banana fibers as a reinforcement material in concrete to improve its mechanical properties. Compressive and flexural tests were performed to determine the strength behavior of banana fiber reinforced concrete (BFRC) at various fiber contents (0.5%, 1.0%, and 1.5%) in the concrete mix. The results indicate that the addition of banana fibers significantly improves the concrete's strength properties, including its flexural and compressive strengths.

Furthermore, the workability of the concrete mix with banana fibers was evaluated using L-Box and U-Box tests, and it was found that the incorporation of fibers did not significantly affect the workability of the mix. Therefore, the use of natural banana fibers in concrete can provide cost-effective, environmentally friendly, and recyclable construction solutions.

Banana fibers, as a byproduct of the banana industry, offer a sustainable alternative to synthetic reinforcing materials. Their abundant availability makes them an attractive choice for enhancing concrete performance while reducing waste and reliance on non-renewable resources. The successful integration of banana fibers in concrete has the potential to facilitate the development of sustainable and durable construction materials.

Based on the experimental results, it is recommended to incorporate banana fibers up to 1.5% by weight of the binder for maximum mechanical performance. Beyond this fiber content, there may be diminishing returns or potential challenges in achieving uniform fiber dispersion.

This research contributes to the growing body of knowledge on the use of natural fibers as reinforcement in concrete. It highlights the positive impact of banana fibers on concrete strength properties and emphasizes their potential as an environmentally friendly and cost-effective solution. Future studies could focus on investigating the long-term durability and performance of BFRC in different environmental conditions to ensure its suitability for practical applications.

In conclusion, the utilization of banana fibers in concrete presents a promising opportunity to enhance mechanical properties while promoting sustainability in the construction industry. The findings underscore the *feasibility and benefits of incorporating banana fibers in concrete mixtures, providing a pathway for the development of innovative and eco-friendly construction materials.*

Keyword: - *Banana fiber , Reinforced concrete, Mechanical properties, Compressive strength, Flexural strength, and Workability*

1. INTRODUCTION-1

Concrete has been extensively used in construction due to its adaptability, durability, and affordability. However, conventional concrete production has negative environmental impacts, including carbon emissions, energy consumption, and depletion of natural resources. Consequentially, there is a growing interest in developing eco-friendly alternatives. Banana fiber-reinforced concrete BFRC is an alternative concrete composition incorporating natural fibers such as banana fiber.

The tropical and subtropical regions are rich in banana fibers derived from agricultural byproducts. These fibers are ideal for reinforcing concrete due to their extraordinary mechanical properties. High tensile strength, flexibility, and durability. In addition, banana fibers can reduce the environmental impact of concrete production and disposal when used as a reinforcement material. They are renewable, biodegradable, and require little energy for extraction and processing.

The construction industry emphasizes inexpensive and environmentally favorable building materials that address economic, social, and environmental concerns in concrete engineering. Fiber reinforcement, such as banana fiber reinforcement, has emerged as a plausible solution. Studies have shown that fiber-reinforced concrete outperforms conventional concrete by integrating fibers that bridge cracks. The properties of concrete are enhanced, and in addition, using banana fibers as a component material has environmental benefits and increases the strength of concrete through effective fissure management [1,2].

The primary purpose of this study was to evaluate and assess the effectiveness of banana fiber as a conventional concrete additive to improve the structural utility of banana fiber-reinforced concrete. The mechanical properties of banana fiber-reinforced concrete were investigated using experimental methodologies. The findings of this study contribute to the development of eco-friendly and sustainable building materials to meet the construction industry's rising demand for cost-effective solutions.

2. METHODS AND PROCEDURE-2

The researchers outline the research design that was selected and provide details about the data collection instrument that was utilized. The procedures that were employed to conduct the study are also described. Additionally, the chapter covers the methods that were utilized to analyze the collected data.

2.1 Research Design-1

The research design of this study was experimental and a quantitative research approach was utilized to gather data on the compressive and flexural strength of pervious concrete samples. The main objective of this study was to create an environmentally sustainable BFRC that could be utilized as a structural component. To achieve this goal, the researchers developed their own mix proportion for banana fibers, which was tested for curing of concrete up to 100% at 7, 14, and 28 days.

Throughout the study, the workability and consistency of the banana fiber reinforced fresh concrete were analyzed by examining its flowing property using both the U-Box Test and the L-Box Test. By utilizing an experimental research design and a quantitative approach, the researchers were able to gather precise and reliable data on the strength properties of the BFRC.

2.2 Local of the Study-2

The study was conducted in a controlled environment at two different testing centers: The Nematec Construction Materials Testing Center and PRIME Materials Testing Services, INC, both of which were located in the Nueva Ecija 2nd District Laboratory. The researchers were assisted by a registered Materials Engineer during the course of the study.

Banana stems used in the study were sourced from San Jose, Nueva Ecija, and were extracted at the same location. To prepare the samples, the researchers took them to Llanera, Nueva Ecija, where they were then cured under controlled conditions. This approach ensured that the environmental conditions of the testing and curing process were consistent throughout the study, thereby increasing the accuracy and reliability of the results.

2.3 Research Instrument-3

a) Flow Test

To evaluate the characteristics of the BFRC, two tests were conducted: The L-box test and the U-box test. The L-box test was utilized to determine the flow of the concrete as well as to assess any blockages caused by the reinforcement. On the other hand, the U-box test was utilized to evaluate the filing ability of the reinforced concrete. These tests were essential in providing a comprehensive analysis of the properties of the BFRC, which were crucial in determining its effectiveness as a sustainable construction material.

b) Mechanical Testing

To assess the strength of the BFRC, the study utilized the Hydraulic Universal Testing Machine, which was available at the accredited private testing laboratories of Nematec Construction Materials Testing Center and PRIME Materials Testing Services, INC. This machine is capable of determining both compressive and flexural strength, which are essential in evaluating mechanical properties of the banana fiber.

The machine was essential in providing reliable and accurate measurements of the concrete's strength properties. Additionally, the use of accredited testing laboratories ensured that the testing process was conducted under standardized conditions, which were critical in minimizing errors and producing dependable results.

2.4 Data Gathering Procedures-4

The researchers will first perform the banana fiber extraction from “Saba” or *Musa acuminata* × *balbisiana* and performed the necessary treatment of the fibers before adding it to the concrete mixture.

a. Banana Fiber Extraction

Banana fibers were extracted from the trunk of banana trees, which served as the primary source of fibers. The extraction process was crucial for obtaining high-quality fibers, and three commonly used methods were employed.

In the first method, the banana trunks were chopped, and the thick, wet stems were cut and peeled into individual layer sheaths after harvesting the banana hands. A worker would flatten a single sheath on the ground and secure one end under a broad, straightedge knife. The sheath was then pulled firmly from under the blade, and the extracted banana fibers were cleaned to remove any particulate matter before being soaked overnight.

The second method involved extracting banana fibers from the bark of the banana tree. By peeling off the brown-green skin from the trunk, a cleaner and whiter area was exposed. Manual extraction using either serrated or non-serrated knives was performed, clamping the peel between a wood plank and the knife and hand-pulling it through to remove resinous particles. The extracted fibers were subsequently sun-dried to achieve a whiter fiber appearance.

In the third method, a section of the banana plant's main stem was cut, and excess moisture was carefully rolled out. Manual removal of impurities such as pigments, broken fibers, and cellulose coating was performed using a comb, followed by washing and drying of the fibers.

After the fibers were extracted, they were sun-dried for at least one week for conditioning purposes. This approach ensured that the banana fibers were thoroughly cleaned and dried, making them suitable for use in the concrete mixture.

It is important to note that the process of obtaining and treating the banana fibers required a significant amount of time and effort. However, the researchers considered this necessary to ensure that the fibers were of high quality and suitable for use in the experiment.

b. Banana Fiber Preparation

To enhance the adhesion properties of the banana fiber, the extracted fibers were soaked in water after being sun-dried. This process helped to remove lignin and other non-cellulosic materials, which could improve the compressive and flexural properties of the treated banana fiber, making it more suitable as an effective additive in a concrete mixture.

The fibers were soaked in water for approximately one hour before being removed and washed with distilled water to ensure that any remaining residue was completely removed. This treatment process was crucial in preparing the banana fibers for use in the concrete mixture, as it helped to optimize the mechanical properties of the fibers, enhancing their strength and durability. All fibers extracted has the same length of 20mm.

The following materials will be used to determine the application of banana fiber as a structural component material:

1) Banana Fiber Reinforced Concrete
    a. Banana Fiber
    b. Cement – Class A
    c. Fine and Coarse Aggregate (washed and cleaned)
    d. Water
2) Proportioning of the Sample
    a. Cement: 1 gallon
    b. Fine Aggregate: 1.5 gallons (or 50% of the total volume of aggregate)
    c. Coarse Aggregate: 1.5 gallons (or 50% of the total volume of aggregate)
    d. Water: 1 quart

To investigate the effectiveness of banana fiber as a reinforcing material, 0.5%, 1%, and 1.5% of banana fiber by volume of concrete was added in making the compressive and flexural, L-Box and U-Box samples. The varying fiber content of the thesis was by weight volume.

The computation for the different fiber percentages is as follows:

a. 0.5% of fiber by volume of concrete = 0.67 g of banana fiber per liter of concrete
b. 1% of fiber by volume of concrete = 1.33 g of banana fiber per liter of concrete
c. 1.5% of fiber by volume of concrete = 2 g of banana fiber per liter of concrete

The size of cube samples used in the compressive and flexural tests is 150x150x150mm, while for the flexural test, we used a sample size of 150x150x450mm.

Table -1: Summary of the different fiber percentages and their corresponding weights

Fiber Percentage	Banana Fiber Weight (g) per liter of concrete
0.5%	0.67
1%	1.33
1.5%	2.0

2.5 Data Gathering Instrument-5

a) Flow Test

The L-box and U-box tests were performed to assess the flow of the concrete and the extent to which it was subjected to blocking by reinforcement. The L-box test measured the flowability of the concrete, while the U-box test measured the filling ability of concrete.

U-Box Test

The Taisei Corporation's Technology Research Center in Japan developed a test, also known as the "box-shaped" test, to assess the filling ability of self-compacting concrete. The test involves a vessel with a central wall dividing it into two compartments, R1 and R2, that are connected by a sliding gate. Reinforcing bars with nominal widths of 13mm are installed at the gate with a center-to-center distance of 50mm, leaving a 35mm open space between the bars. Approximately 20 liters of concrete are poured into the left compartment, and then the gate is lifted, allowing the concrete to flow upwards into the right compartment. The height of the concrete in both compartments is measured.

Although the equipment for this test may be challenging to construct, the test itself is simple to perform and offers a direct assessment of the filling ability of the concrete. It is critical to achieve the required filling ability, which is precisely what this test measures. However, it is worth noting that the 35 mm separation between the reinforcement portions may be too small. Moreover, it remains unclear what the acceptable filling height is, as a height of less than 30 cm may not be sufficient.

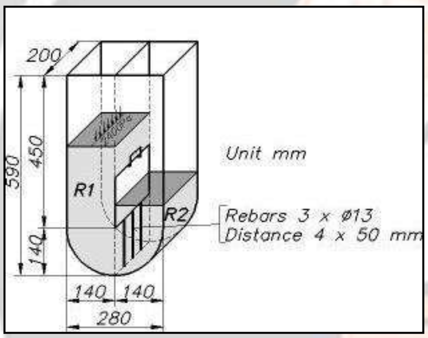

Fig -1: U-Box Apparatus


Fig -2: Improvised U-Box Apparatus

By following this procedure, the researchers were able to obtain accurate measurements of the filling height of the concrete mix with banana fiber in the U-box-shaped test apparatus.

1) Level the U-box-shaped test apparatus horizontally using a spirit level that has been moistened on its inner surface to prevent the concrete from sticking to it.
2) Pour the 20 liters of concrete mix with banana fiber into the left compartment of the U-box-shaped test apparatus without compacting it and remove any excess material from the top surface.
3) Allow the apparatus to sit undisturbed for up to one minute.
4) Raise the sliding gate to allow the concrete to flow into the right compartment of the apparatus.
5) Measure the height of the concrete surface in both compartments and record the values as h1 and h2.
6) Calculate the filling height by subtracting h2 from h1.

L-Box Test

The L-box test is a method used to assess the passing ability of self-compacting concrete when it comes to filling spaces between reinforcement. The test was originally based on a Japanese concept for underwater concrete and was described by Peterson. The L-box test evaluates how well the concrete flows and how much it is obstructed by the reinforcement bars.

The device used in the L-box test is a rectangular box with an "L"-shaped cross-section, consisting of a vertical and a horizontal portion, and a movable gate with vertical lengths of reinforcement bars inserted in front of it. Once concrete is poured into the vertical section, the gate is lifted, allowing the concrete to flow into the horizontal section. When the flow has stopped, the height of the remaining concrete in the vertical section (H2/H1 in the diagram) is measured to determine the height of the concrete at the end of the horizontal section. The slope of the concrete as it is at rest is also measured, as it indicates the passing ability of the concrete and how well the bars allow concrete to flow through them.

To perform the test, approximately 14 liters of concrete are required. The apparatus should be placed on firm ground, ensuring the sliding gate can open and close freely. The inside surface of the apparatus should be moistened and excess water removed. The vertical section of the apparatus is then filled with the concrete sample after allowing it to stand for 1 minute. The sliding gate is lifted, allowing the concrete to flow into the horizontal section at the same time the stopwatch is started. The time for the concrete to reach the 200 and 400 marks is recorded once the concrete stops flowing the distances h1 and h2 are measured the blocking ratio h2/ h1 is then calculated it is essential to complete the entire test within 5 minutes note the provided information has been paraphrased and summarized to provide clearer instructions for the test.

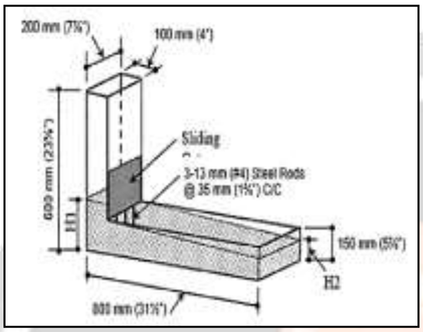

Fig -3: L-box Apparatus

Fig -4: Improvised L-box Apparatus

By following this procedure, the researchers were able to obtain accurate measurements of the filling height of the freshly mixed concrete in the L-box test apparatus.

1) Ensure that the L-box test apparatus is free from any impurities and the inner surface is dampened to prevent the concrete from sticking to it.
2) Level the apparatus horizontally using a spirit level.
3) Fill the freshly mixed concrete (14 liters) into the vertical hopper of the apparatus up to the top surface and level it using a trowel.
4) Wait for one minute, and then lift the gate to allow the concrete to flow into the horizontal tank.
5) After the concrete has completely stopped flowing, measure the height of the remaining concrete in the vertical section of the apparatus and record it as h2.
6) Measure the height of the concrete in the horizontal section of the apparatus and record it as h1.
7) Calculate the filling height by dividing h2 by h1.

b) Mechanical Testing

This test was performed using the Hydraulic Universal Testing Machine available at accredited private testing laboratories in Nematec Construction Materials Testing Center and PRIME Materials Testing Services, INC. This machine determines the compressive and flexural strength which will be used to determine the strength of the banana fiber.

Compressive Strength Test

The compressive strength test is essential in determining the maximum load a material can bear before deformation or fracture. Here are the steps for conducting a compressive strength test on pervious concrete reinforced with BFs in accordance with the ASTM C39/C39M guidelines:

The following procedures were conducted by the researchers:

1) Preparation of samples: Using an improvised cube mold with measurement of 150x150x150mm, incorporate the banana fiber to the freshly mixed concrete and the pour it to the mold.
2) Curing of samples: After cutting the specimens, cure them in a moist environment for 7, 14, and 28 days to allow the concrete to set and gain strength.

3) Conducting pre-test measurements: Measure and record the dimensions and weight of the samples to calculate their density before applying any load.
4) Positioning of samples: Place the sample in the compression testing machine with the load-bearing surfaces facing upward and downward, and align them carefully.
5) Applying the load: Start applying the load to the sample at a steady rate, increasing the load gradually until the sample fails or fractures.
6) Recording the maximum load: Record the maximum load that the sample can bear before failure or fracture.
7) Repeat the test: Repeat the test on additional samples to obtain an average compressive strength value.

Flexural Strength Test

The flexural strength test is a method for determining the bending strength of a material, typically used on pervious concrete reinforced with BFs. The test involves placing a rectangular beam of the material on two supports and applying a load at the center of the beam until it breaks. This is in accordance to the book of Jose Reynaldo Cuna, MSCE-G (UPD) entitled: *Fundamentals of Concrete Technology.*

The following steps were conducted in conducting a flexural strength test:

1) Clean and dry the surface of the beam, and mark the center of the beam.
2) Place the beam horizontally on two supports, with the marked center at the midpoint between the two supports.
3) Load the beam at the center using a universal testing machine, applying a load at a rate of around 0.2 to 0.4 MPa per second, until the beam breaks.
4) Record the maximum load at which the beam breaks.

2.6 Statistical Treatment-6

The statistical aspect of this research study came from Universal Testing Machine, U-box, and L-Box Apparatus that gave the data in real time upon the testing. All the data were tabulated and presented in a graphical form for easier analysis. For the L-Box test, U-Box Test, compressive and flexural strength test, the following applies:

A. Flow test

The flow test is a method used to assess the quality of high or very high workable concrete before it collapses. It is used to determine the consistency and cohesion of the concrete. Two flow tests, namely the L-Box and U-Box test, are used to evaluate the concrete's passing ability.

L-Box Test

The L-box test, originally developed by Peterson, is a test method specifically designed for evaluating the flow characteristics and potential blocking issues of self-compacting concrete, inspired by a Japanese design intended for underwater concrete applications

Table -2: Standard value of acceptance for L-box Test

Blocking Value	Interpretation

<0.8	Viscosity is too high
0.8 – 1.0	Acceptable passing ability of Concrete
>1.0	Indicates false results or bleeding

The blocking value is computed as the ratio of h2/h1, where h2 is the height of the concrete at the end of flow and h1 is the height of the concrete in the vertical box next to the obstruction.

The L-box test considers a blocking number between 0.80 and 1.0 as ideal. A value lower than 0.80 may suggest high viscosity, while a value near 1 may lead to false outcomes. Furthermore, visual observations during the test can help in evaluating the passing ability and segregation resistance of the concrete. If the concrete forms a plateau in front of the reinforcement steel bars, it may indicate blockage or segregation issues.

U-Box Test

The U-box test, also known as the box-shaped test, was developed by the Technology Research Centre of the Taisei Corporation in Japan it is utilized to assess the filling ability of self-compacting concrete.

Table -3: Standard value of acceptance for U-box Test

Value of h1-h2 (height in mm)	Interpretation
< 0	Low viscosity and good flowability
0-10 mm	Very good flowability
10-20 mm	Good flowability
20-30 mm	Fair flowability

> 30 mm	Poor flowability and possibility of blockage

The h1-h2 height difference in millimeters between the top surface of the concrete in the U-box and the height of the concrete next to the vertical side of the U-box is used to interpret the flowability of concrete in the U-box test. The table provides the interpretation of the values of h1-h2, with smaller values indicating better flowability. The U-box test involves pouring concrete into a U-shaped box with reinforcement bars placed along its length. The difference in height h1-h2 is measured to evaluate the passing ability of SCC through tight spaces and congested reinforcement. A value of less than 10 mm indicates very good flowability, while values above 30 mm indicate poor flowability and the possibility of blockage. The interpretation table serves as a basis for evaluating the passing ability of concrete, which is an essential characteristic for concrete to analyze its workability.

B. Mechanical Testing

Table -4: Item 311 of the DPWH Standard Specifications for Highways, Bridges, and Airports, Volume II – Highways

Age of Concrete	Compressive Strength (MPa)	Flexural Strength (Mpa)
7 days	20.0	3.5
14 days	24.0	4.5
28 days	28.0	5.0

The table shows the standard compressive and flexural strength requirements for Class A concrete based on the age of the concrete. The compressive strength of the concrete should be at least 20 MPa at 7 days, 24 MPa at 14 days, and 28 MPa at 28 days. On the other hand, the flexural strength of the concrete should be at least 3.5 MPa at 7 days, 4.5 MPa at 14 days, and 5 MPa at 28 days, based on midpoint loading. Meeting these strength requirements ensures that the concrete is durable and can withstand the stresses it will be subjected to.

C. Two-Way ANOVA Test Without Replication

This is used to determine the following: (1) significant difference regarding the compressive and flexural strength of BFRC in terms of varying fiber content; (2) significant difference in the performance of Banana fibre reinforced concrete in compressive and flexural strength between its curing time.

Table -5: Two-Way ANOVA Test without Replication

Source of Variation	SSS	DF	MSS	F
Rows	SSrow	DFrow	MSSrow	F = MSSrow
Columns	SScol	DFcol	MSScol	F = MSScol
Error	SSerr	DFerr	MSSerr	
Total				

Step-by-step procedures on how the researchers conducted the Two-Way ANOVA Test Without Replication in determining the significant difference in the compressive and flexural strength of BFRC in terms of varying fiber content and the effect of curing time on the performance of BFRC:

1) Identify the two sources of variation: rows (fiber content) and columns (curing time).
2) Compute the sum of squares (SS), degree of freedom (DF), and mean sum of squares (MSS) for each source of variation using the appropriate formulas.
3) Calculate the F-value for each source of variation by dividing the MSS by the corresponding DF.
4) Compute the error sum of squares, degree of freedom, and mean sum of squares using the appropriate formulas.
5) Compute the total sum of squares.
6) Compare the calculated F-values of the rows and columns to the critical F-value to determine if there is a significant difference.
7) If the calculated F-value is greater than the critical F-value, it indicates a significant difference in that source of variation.
8) Interpret the results and draw conclusions based on the analysis.

D. One-Way ANOVA Single Factor

This was used to determine the significant difference in addition of banana fiber as a reinforcement in concrete in workability and consistency of the mechanical properties, such as (1) L-box Test; and (2) U-box Test.

Table -6: One-Way ANOVA Test Single Factor

Source of Variation	SSS	DF	MSS	F
Between	SSbet	DFbet	MSSbet	F = MSSbet/MSSwit

Within	SSwit	DFwit	MSSwit	
Total	SStol	DFtol		

Steps conducted by the researcher in performing a One-Way ANOVA in Excel based on the procedure used in the thesis:

1) Open Microsoft Excel and enter the data for the L-Box and U-Box tests in separate columns.
2) Calculate the mean and standard deviation for each group (i.e., control sample and samples with varying levels of banana fiber).
3) Calculate the total sum of squares (SStol) by subtracting the overall mean from each individual score, squaring the result, and adding all of these values together.
4) Calculate the sum of squares between groups (SSbet) by multiplying the square of the difference between each group mean and the overall mean by the number of scores in that group and summing across all groups.
5) Calculate the sum of squares within groups (SSwit) by subtracting the sum of squares between groups from the total sum of squares.
6) Calculate the degrees of freedom between groups (DFbet) by subtracting 1 from the number of groups.
7) Calculate the degrees of freedom within groups (DFwit) by subtracting the total number of scores from the number of groups.
8) Calculate the mean square between (MSSbet) by dividing the sum of squares between groups by the degrees of freedom between groups.
9) Calculate the mean square within (MSSwit) by dividing the sum of squares within groups by the degrees of freedom within groups.
10) Calculate the F-value by dividing the mean square between by the mean square within.
11) Compare the calculated F-value to the critical F-value at the chosen level of significance ($\alpha = 0.05$) which is the standard and the degrees of freedom between and within groups to determine if there is a significant difference between groups.
12) Interpret the results and draw conclusions regarding the significant difference in the workability and consistency of the mechanical properties of concrete with banana fiber reinforcement compared to the control sample.

E. Extrapolation in Excel is a statistical technique used to predict values beyond the range of existing data points. In the context of the thesis, extrapolation was employed by the researchers to estimate the compressive and flexural strength of banana fiber-reinforced concrete (BFRC) samples with fiber content levels beyond those tested directly. The researchers initially conducted compressive and flexural strength tests on BFRC samples with fiber content levels of 0.5%, 1%, and 1.5%, representing the available data points. They then utilized extrapolation to predict the strength values for BFRC samples with higher fiber content levels, specifically 2%, 2.5%, and 3%.

Step-by-Step Extrapolation in Excel (as conducted by the researchers):

1) Open Microsoft Excel and create a new worksheet.
2) Enter the available data points for the compressive and flexural strength tests in separate columns. For example, in column A, enter the fiber content levels (0.5%, 1%, 1.5%), and in column B, enter the corresponding strength values obtained from the tests.
3) In column C, enter the desired fiber content levels for extrapolation (2%, 2.5%, 3%).
4) In an empty cell, use the TREND function to perform the extrapolation calculation for compressive strength. For example, if the empty cell is D2, enter the formula: "=TREND(B2:B4, A2:A4, C2:C4)". This formula extrapolates the compressive strength value for the corresponding fiber content level in cell C2 based on the available data points in columns B and A.

5) Press Enter to calculate the extrapolated compressive strength value for the first desired fiber content level.
6) Copy the formula in cell D2 and paste it into the remaining cells in column D corresponding to the other desired fiber content levels (2.5% and 3%).
7) Repeat steps 4-6 for the flexural strength extrapolation. For example, if the empty cell for flexural strength is E2, enter the formula: "=TREND(B2:B4, A2:A4, C2:C4)".
8) Press Enter to calculate the extrapolated flexural strength value for the first desired fiber content level.
9) Copy the formula in cell E2 and paste it into the remaining cells in column E corresponding to the other desired fiber content levels (2.5% and 3%).
The resulting extrapolated compressive and flexural strength values will be displayed in columns D and E, respectively, adjacent to the corresponding fiber content levels in column C.

3. PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA-3

Several tests were carried out to determine the properties of the concrete. The test was run to determine the ideal mix ratio of various components for concrete to reach its maximum strength.

A. Flow Test

The flow test is used to evaluate the degree to which high or very high workable concrete is beforehand it eventually shows slump collapse. It provides insight into the consistency and cohesion of the concrete's quality. Two flow tests were used to determine the passing ability of the consistency and cohesion of the concrete which includes the L Box and U Box test.

L-Box Test

Table -7: Summary Result of L-box Test using BFRC

Sample	H1	H2	H2/H1	Time(s)	Interpretation
A	45	10	0.2222222	4.1	Viscosity is too high
B	46	8.5	0.1847826	4.3	Viscosity is too high
C	45	8	0.1777778	4.2	Viscosity is too high

The table summarizes the results of the L-box test using Banana FRC for three different samples: A, B, and C. Each sample was tested for the height difference (in mm) between the top surface of the concrete in the L-box and the height of the concrete next to the vertical side of the L-box (H1 and H2, respectively). The ratio of H2/H1 was also calculated as an indicator of the passing ability of the concrete through tight spaces and congested reinforcement, with smaller values indicating better flowability.

Sample A had an H1 value of 45 mm and an H2 value of 10 mm, resulting in an H2/H1 ratio of 0.222. Sample B had an H1 value of 46 mm and an H2 value of 8.5 mm, resulting in an H2/H1 ratio of 0.1847. Finally, Sample C had an H1 value of 45 mm and an H2 value of 8 mm, resulting in an H2/H1 ratio of 0.1777. All three samples had an H2/H1 ratio above the ideal range of 0.8-1.0, indicating issues with viscosity and poor passing ability of the concrete.

Table -8: Summary Result of U-box Test using BFRC

Sample	H1	H2	H1-H2	Time (s)	Interpretation
A	30	20	10	4.1	Very good flowability
B	28	20	8	3.4	Very good flowability
C	41	8	33	3	Poor flowability and possibility of blockage

The table shows the results of the U-box test using different samples of concrete, labeled A, B, and C. For sample A, the height of the concrete in the U-box was 30 mm and the height of the concrete next to the vertical side was 20 mm, resulting in a height difference of 10 mm. The time taken for the concrete to flow through the U-box was 4.1 seconds, and the interpretation of the result was "very good flowability."

Sample B had a height difference of 8 mm and flowed through the U-box in 3.4 seconds, resulting in a similar interpretation of "very good flowability." However, for sample C, the height difference was 33 mm, indicating poor flowability and a possibility of blockage. The concrete took 3 seconds to flow through the U-box.

Overall, the results suggest that samples A and B had good flowability, while sample C had poor flowability and was at risk of blockage. The U-box test is an important method for evaluating the passing ability of concrete through tight spaces and congested reinforcement, and the results provide valuable information for improving the quality of the concrete mixture.

A. Mechanical Test

Compressive Strength Test

The most frequent test on hardened concrete is the compression test, in part because it is simple to execute and in part because most of the desirable features of concrete are qualitatively related to its compressive strength. The specimen used for the compressive test is either cubical or cylindrical in shape. Parts of a beam that have undergone flexure testing are sometimes used to determine the compression strength of concrete. The compressive test was done in NEMATEC which is an accredited construction materials laboratory located in Bantug Norte, Cabanatuan City.

The following tables represent the Compressive strength of the BFRC as a structural component.

Table -9: Compressive Strength Test Results of BFRC in 7 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Compressive Strength	
					Psi	Mpa
I A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	300	2.07
II A	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	379	2.61
III A	Concrete Tube Fiber 1.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	599	4.13

The table above shows the compressive test of banana fiber by curing it for 7 days. The materials used were concrete tube, fibers starting form .5%, 1% and 1.5% content, 1 gallon of cement, 3 gallons of gravel, and 1 quart of water. For the first sample that has a content of .5% of fiber, the gathered pound per square inch (PSI) is 300 with MPa of 2.07. For the second sample that has a content of 1% of fiber, the gathered PSI is 379 with the MPa of 2.61 and for the third sample that has a content of 1.5% of fiber, the gathered PSI is 599 with the MPa of 4.13.

Table -10 Compressive Strength Test Results of BFRC in 14 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Compressive Strength	
					Psi	Mpa
I A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	616	4.25
II A	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	641	4.42
III A	Concrete Tube Fiber 1.5% , Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	668	4.61

The table above shows the compressive test of banana fiber by curing it for 14 days. The materials used were concrete tube, fibers starting form .5%, 1% and 1.5% content, 1 gallon of cement, 3 gallons of gravel, and 1 quart of water. For the first sample that has a content of .5% of fiber, the gathered pound per square inch (PSI) is 616 with MPa of 4.25. For the second sample that has a content of 1% of fiber, the gathered PSI is 641 with the MPa of 4.42 and for the third sample that has a content of 1.5% of fiber, the gathered PSI is 668 with the MPa of 4.61.

Table -11: Compressive Strength Test Results of BFRC in 28 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Compressive Strength	
					Psi	Mpa
I A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	1751	12.07
II A	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	2000	13.79
III A	Concrete Tube Fiber 1.5% , Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	2394	16.51

The table above shows the compressive test of banana fiber by curing it for 28 days which by evidence shows that it possesses the maximum strength that is need for it to be suitable in reinforcement of concrete using banana fiber in terms of compressive strength. The materials used were concrete tube, fibers starting form .5%, 1% and 1.5% content, 1 gallon of cement, 3 gallons of gravel, and 1 quart of water. For the first sample that has a content of .5% of fiber, the gathered pound per square inch (PSI) is 1751 with MPa of 12.07. For the second sample that has a content of 1% of fiber, the gathered PSI is 2000 with the MPa of 13.79 and for the third sample that has a content of 1.5% of fiber, the gathered PSI is 2394 with the MPa of 16.51.

Table -12: Compressive Strength Test Results of BFRC in 7, 14, and 28 days

Sample	Fiber Content	Compressive Strength (MPa)		
		7 days	14 days	28 days
I-A	0.5	2.07	4.25	12.07

I-B	1	2.61	4.42	13.79
I-C	1.5	4.13	4.61	16.51

The table shows that, for the three various fiber addition ratios, a significant increase in compressive strength is attained when compared to the normal concrete. Moreover, it is clear that the outcomes for the 0.5% addition of banana fibers are better than those for the banana reinforced concrete after 28 days of curing. In addition, it was shown that the strength of the concrete with 1% and 1.5% grew with the lengthening of the curing period. It means that Compressive strength is influenced by Hydration Rate. One of the factors contributing to the composite's rise in compressive strength is likely complete hydration. The addition of fibers to the composite improves the toughness, which results in an increase in compressive strength. The presence of the material in banana fiber affects the composite's compressive strength.

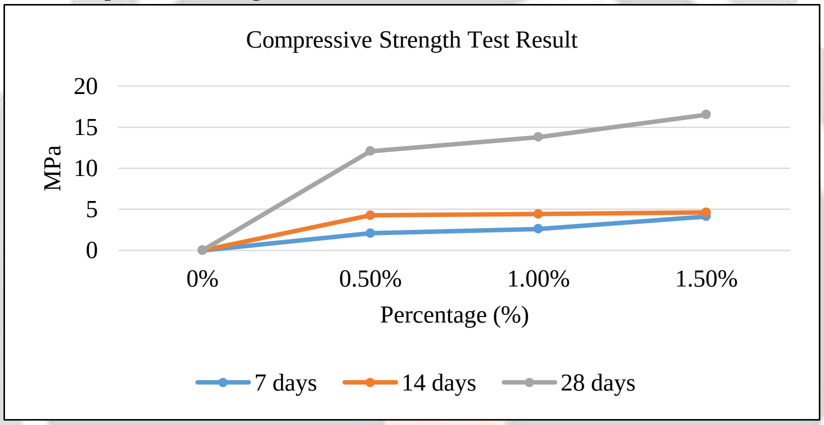

Chart -1: Graphical Representation of Compressive Strength Test Results

The figure above shows the compressive strength of banana reinforced concrete wherein comparing to the required compressive strength of normal concrete based on Department of Public Works and Highways (DPWH) which stated that the the mixture shall have a minimum compressive strength of 1.4 MPa, it is shown evidently that the compressive strength of banana reinforced concrete passed the require compressive strength of normal concrete and are suitable to use in structural properties.

Flexural Strength Test

Flexural strength of concrete is a measure of the tensile strength of concrete that describes the amount of stress and force in an unreinforced concrete, such as structural components like slabs or beams, which can endure or resist bending failure. The flexural test was done in PRIME Materials Testing Services located in D.S Garcia, Cabanatuan City. The following tables represent the flexural midpoint strength of the BFRC as a structural component.

Table -13: Flexural Strength Test Results of BFRC in 7 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Strength, psi, Flexural, Compressive
A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	414.68 psi (2.85 MPa)
B	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	544.76 psi (3.75 MPa)
C	Concrete Tube Fiber 1.5% , Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	7	663.05 psi (4.57 MPa)

The result from the above table shows that the highest reading of flexural strength is Sample C with the fiber content of 1.5% with the psi of 663.05 and 4.57 MPa followed by Sample B with the fiber content of 1% with the psi of 544.76 and 3.75 MPa and lastly the lowest reading is Sample A with the fiber content of .5% with the psi of 414.68 and 2.85 MPa.

Table -14: Flexural Strength Test Results of BFRC in 14 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Strength, psi, Flexural, Compressive
A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	679.42 psi (4.66 MPa)
B	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	671.48 psi (4.63 MPa)

C	Concrete Tube Fiber 1.5% , Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	14	743.15 psi (5.12 MPa)

The result from the above table shows that the highest reading of flexural strength is Sample C with the fiber content of 1.5% with the psi of 743.15 and 5.12 MPa followed by Sample A with the fiber content of .5% with the psi of 679.42 and 4.68 MPa and lastly the lowest reading is Sample B with the fiber content of 1% with the psi of 671.48 and 4.63 MPa.

Table -15: Flexural Strength Test Results of BFRC in 28 days

Sample	Parts of Structure Station Represented	Date Sampled	Date Tested	Age in days	Strength, psi, Flexural, Compressive
A	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	1230.95 psi (8.48 MPa)
B	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	1318 psi (9.09 MPa)
C	Concrete Tube Fiber 1.5% , Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	4/4/2023	4/11/2023	28	1719 psi (11.85 MPa)

The result from the above table shows that the highest reading of flexural strength is Sample C with the fiber content of 1.5% with the psi of 1719 and 11.85 MPa followed by Sample B with the fiber content of 1% with the psi of 1318 and 9.09 MPa and lastly the lowest reading is Sample B with the fiber content of 1% with the psi of 1230.95 and 8.48 MPa.

Table -16: Flexural Strength Test Results of BFRC in 7, 14, and 28 days

Sample	Fiber Content	Flexural Strength (Mpa)		
		7 days	14 days	28 days
I-A	0.5	2.85	4.68	8.48
I-B	1	3.75	4.63	9.09
I-C	1.5	4.57	5.12	11.85

The result from the above table shows that the highest reading of flexural strength is Sample C with the fiber content of 1.5% with the psi of 1719 and 11.85 MPa followed by Sample B with the fiber content of 1% with the psi of 1318 and 9.09 MPa and lastly the lowest reading is Sample B with the fiber content of 1% with the psi of 1230.95 and 8.48 MPa.

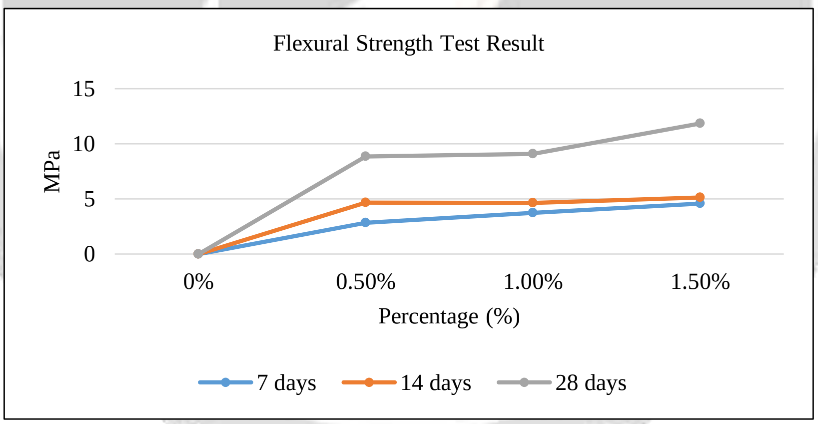

Chart -2: Graphical Representation of Flexural Strength Test Results

Flexural strength tests utilizing two-point loading were performed at the graph of 7, 14, and 28 days of curing to determine the flexural strength of the concrete composite beams cast using banana fibers. The figure shows that there is a significant increase in flexural strength when compared to that for the three varied quantities of fibers added. However, it became apparent that the results for 0.5% addition of banana fibers showed that the flexural strength was more than for a 28-day curing period that of the control beams. Additionally, it was noted that when the curing time raised, the strength of the control beam and the beams cast with 1% and 1.5% increased as well. Based on the standards of DPWH, a flexural strength of not less than 3.8 MPa when tested by the third-point method or 4.5 MPa when tested by the mid-point method at 14 days in accordance with AASHTO T 97 "Standard Method of Test for Flexural Strength of Concrete". This shows that upon comparison, the flexural strength required for the normal concrete was met by the flexural strength of banana reinforced concrete making it suitable for structural properties.

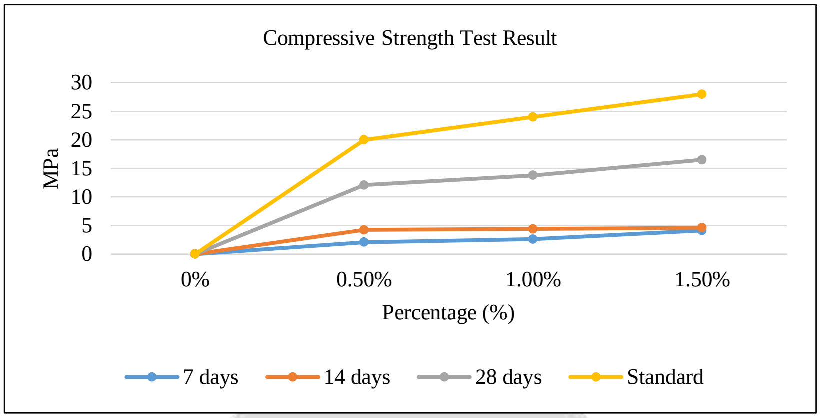

Chart -3: Comparison of Compressive Strength of Banana Fiber Reinforced Concrete and DPWH Standard

The graph shows the results of compressive strength testing for banana fiber reinforced concrete with varying fiber content and age of concrete. Three fiber content levels were tested: 0.5%, 1%, and 1.5%. The concrete samples were tested at three different ages: 7 days, 14 days, and 28 days.

Compared to the standard compressive strength values set by DPWH (20 MPa at 7 days, 24 MPa at 14 days, and 28 MPa at 28 days), the banana fiber reinforced concrete samples generally had lower compressive strengths at 7 and 14 days, but had higher compressive strengths at 28 days. This indicates that the addition of banana fiber as reinforcement may result in slower early-age strength development, but may lead to improved long-term strength.

Furthermore, it can be observed that the compressive strength of the banana fiber reinforced concrete increased as the fiber content increased, and as the age of concrete increased. The highest compressive strength values were obtained for sample I-C, which had a fiber content of 1.5% and an age of 28 days.

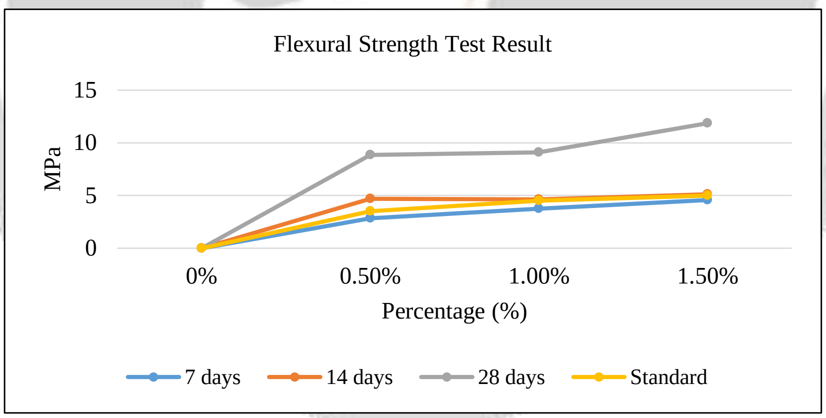

Chart -4: Comparison of Flexural Strength of Banana Fiber Reinforced Concrete and DPWH Standard

The bar chart compares the flexural strength of banana fiber reinforced concrete samples with varying fiber content and age to the standard flexural strength of DPWH. The samples were prepared with 0.5%, 1%, and 1.5% banana fiber content and tested at 7, 14, and 28 days equivalent ages.

The results indicate that the flexural strength of the concrete generally increases with age and fiber content. At 7 days, all samples with banana fiber content showed lower flexural strength compared to the DPWH standard. However, at 14 and 28 days, the samples with 1% and 1.5% banana fiber content exhibited higher flexural strength than the standard.

Analysis Using Statistical Tool (Two-Way Anova without Replication)

Table -17: Summary Result of Mechanical Tests in BFRC

Mechanical Tests	Age in Days	Concrete Tube Fiber 0.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	Concrete Tube Fiber 1 %, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart	Concrete Tube Fiber 1.5%, Cement 1 Gallon, Gravel 3 Gallon, Water 1 quart
Compressive Strength (psi)	7	300	379	599
	14	616	641	668
	28	1751	2000	2394
Flexural Strength (psi)	7	414.68	544.76	663.05
	14	679.42	671.78	743.15
	28	1230.95	1318	1719

The results of concrete containing 0.5%, 1% and 1.5% of banana fiber at 7, 14 and 28 days were analyzed, and the results showed that the compressive strength and flexural strength of concrete increased when banana fiber content increases. This can be attributed to the reinforcing effect of the banana fibers, giving the overall strength and stability of the concrete. At 7 days, concrete with 1.5% banana fiber had the highest tensile strength and strength, while concrete with 1% banana fiber exhibited higher strength at 14 and 28 days. Furthermore, the results show that the use of banana fibers as a concrete reinforcing agent can be an effective and sustainable alternative to conventional materials.

In summary, the compressive and flexural strength test results show that increasing the banana fiber content of the concrete significantly improves its strength and durability at 7 days, concrete a banana fibers containing 1.5% showed the highest strength, while at 14 and 28 days, concrete with 1 % banana fiber showed the highest strength If banana fiber can be a reactive and non-reactive material environmentally friendly reinforcements commonly used in concrete.

Table -18: Significant difference regarding the compressive and flexural strength of BFRC

Banana Fiber Reinforced Concrete	F-Value	F-Critical	Decision	Interpretation
Varying Percentage	9.45	3.32	Reject H_o	With Significant Difference

Since the F-value of 9.45 is greater than the F-critical value of 3.32 at 0.05 level of significance, then reject H_o. Therefore, there is a significant effect regarding the compressive and flexural strength of BFRC in terms of fiber content such as: (1) 0.5 % of banana fiber; (2) 1.0 % of banana fiber; (3) 1.5 % of banana fiber. Several studies have investigated the effect of adding banana fiber to concrete, and have found that it can significantly improve various mechanical properties. Kesavraman [10] reported that using 2% banana fibers by volume led to a substantial increase in compression, split, and flexural strength up to 29.6%, 30.7%, and 179%, respectively, compared to ordinary concrete after 28 days. Similarly, Afraz & Ali [1] found that adding 0.2% of banana fiber can improve the tensile strength of concrete. It has also reported that using modified banana fibers can enhance the flexural, split tensile, and flexural strengths of concrete. Overall, these studies suggest that incorporating banana fiber in different percentages can have a significant impact on various properties of concrete, such as compressive, tensile, and flexural strengths, which can improve over time.

Table -19: Significant difference in the performance of BFRC in compressive and flexural strength between its curing time.

Banana Fiber Reinforced Concrete	F-Value	F-Crit	Decision	Interpretation
Curing Time	82.06	0.004	Reject Ho	With Significant Difference

The table depicts that the Mechanical Test F-value of 82.06 is greater than the F-critical value of 0.004 at 0.05 level of significance, then reject H_o. Therefore, there is a significant difference in the performance of BFRC in compressive and flexural strength between its curing time.

Compressive strength tests and flexural strength tests are two important determinants of concrete quality. Based on the standards of the DPWH in the Philippines, concrete is tested for compressive strength at 7, 14, and 28 days. The results show that strength increases significantly with increasing concrete age. The strength of Class A concrete at 7 days is 20 MPa, while it increases to 30 MPa at 14 days and 35 MPa at 28 days. Class A concrete has a flexural strength of 4.5 MPa at 28 days with center load. The data clearly show that concrete is allowed to cure and age before applying heavy loads quality. Based on the standards of the DPWH in the Philippines, concrete is tested for compressive strength at 7, 14, and 28 days. The results show that strength increases significantly with increasing concrete age. The strength of Class A concrete at 7 days is 20 MPa, while it increases to 30 MPa at 14 days and 35 MPa at 28 days. Class A concrete has a flexural strength of 4.5 MPa at 28 days with center load. The data clearly show that concrete is allowed to cure and age before applying heavy loads.

Table -20: Compressive Strength Results and Extrapolated Values for Different Fiber Content Levels

Varying Fiber Content	7 Days	14 Days	28 Days
0.5%	300	616	1751
1%	379	641	2000

1.5%	599	668	2394
2%	819	695	2788
2.5%	1039	722	3182
3%	1259	749	3576

Table 20 presents the results of the compressive strength tests conducted at different time intervals (7 days, 14 days, and 28 days) for various fiber content levels in banana fiber-reinforced concrete. The available data points include the compressive strength values for fiber content levels of 0.5%, 1%, and 1.5%. Additionally, the compressive strength values for fiber content levels of 2%, 2.5%, and 3% were predicted using extrapolation in Excel.

At the 7-day mark, the compressive strength values for the tested fiber content levels were 300 psi, 379 psi, and 599 psi for 0.5%, 1%, and 1.5% respectively. As the curing period increased to 14 days, the compressive strength improved, reaching 616 psi, 641 psi, and 668 psi for the corresponding fiber content levels. Finally, at 28 days, the compressive strength continued to increase, with values of 1751 psi, 2000 psi, and 2394 psi for the respective fiber content levels.

Using extrapolation in Excel, the researchers were able to predict the compressive strength values for additional fiber content levels. The results showed that as the fiber content increased to 2%, 2.5%, and 3%, the compressive strength also increased. The predicted values at 28 days were 2788 psi, 3182 psi, and 3576 psi, respectively.

This table provides a comprehensive overview of the compressive strength results at different time intervals and allows for a comparison between the tested fiber content levels and the predicted values achieved through extrapolation in Excel.

Table -21: Flexural Strength Results and Extrapolated Values for Different Fiber Content Levels

Varying Fiber Content	7 Days	14 Days	28 Days
0.5%	414.68	679.42	1230.95
1%	544.76	671.78	1318
1.5%	663.05	743.15	1719

2%	781.34	814.52	2120
2.5%	899.63	885.89	2521
3%	1017.92	957.26	2922

The table displays the results of the flexural strength tests conducted on concrete samples with different fiber content levels at 7, 14, and 28 days. Additionally, it includes extrapolated values for the fiber content levels of 2%, 2.5%, and 3% obtained using extrapolation in Excel.

The flexural strength values are expressed in pounds per square inch (psi). The data highlights the influence of the fiber content on the flexural strength of the concrete samples. Generally, an increase in the fiber content corresponds to an improvement in flexural strength.

The initial tested fiber content levels yielded flexural strength values ranging from 414.68 psi to 1017.92 psi at 7 days, 671.78 psi to 957.26 psi at 14 days, and 1230.95 psi to 2922 psi at 28 days.

Additionally, through extrapolation in Excel, the table presents predicted flexural strength values for the fiber content levels of 2%, 2.5%, and 3%. These extrapolated values provide estimates of the flexural strength for higher fiber content levels, which were not directly tested in the experiment.

By examining the table, researchers can gain insights into the relationship between fiber content and flexural strength in the concrete samples over time. The results and extrapolated values contribute to a better understanding of the potential impact of varying fiber content levels on the flexural strength properties of the concrete.

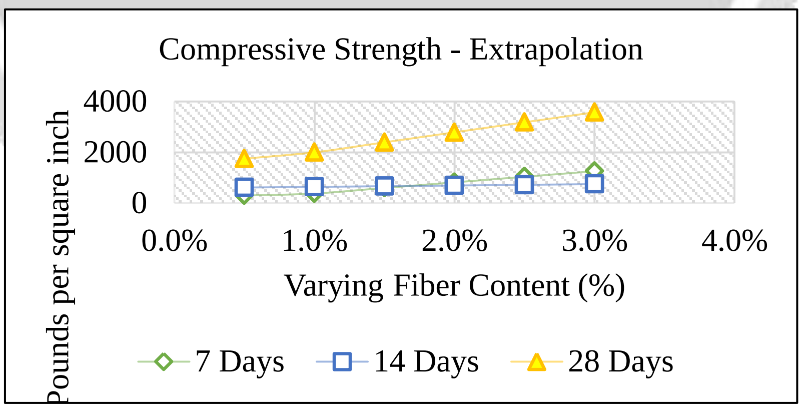

Chart -5: Compressive Strength – Extrapolation

The line graph presents the results of the compressive strength test conducted on banana fiber-reinforced concrete (BFRC) samples at different time intervals. The available data points for the compressive strength, obtained from tests conducted at 7, 14, and 28 days, are plotted on the graph. Additionally, the predicted values for the compressive strength at 2%, 2.5%, and 3% fiber content levels, obtained through extrapolation using Excel, are included.

The x-axis of the graph represents the fiber content levels in percentage (%), ranging from 0.5% to 3%. The y-axis represents the compressive strength measured in pounds per square inch (psi). Each data point on the graph represents the compressive strength value obtained at a specific fiber content level and time interval.

The graph illustrates a continuous line connecting the available data points at 0.5%, 1%, and 1.5% fiber content levels for the corresponding time intervals of 7, 14, and 28 days. This line represents the observed trend in compressive strength as the fiber content increases.

In addition to the observed data, the graph includes a line segment extending beyond the available data range, representing the predicted compressive strength values at 2%, 2.5%, and 3% fiber content levels. These predicted values were obtained using extrapolation in Excel, allowing for an estimation of the compressive strength beyond the tested fiber content levels.

The line graph visually demonstrates the relationship between fiber content and compressive strength in BFRC samples, highlighting the increase in strength with higher fiber content levels. It provides an overview of both the observed data and the extrapolated values, offering insights into the potential compressive strength performance at higher fiber content levels not directly tested in the study.

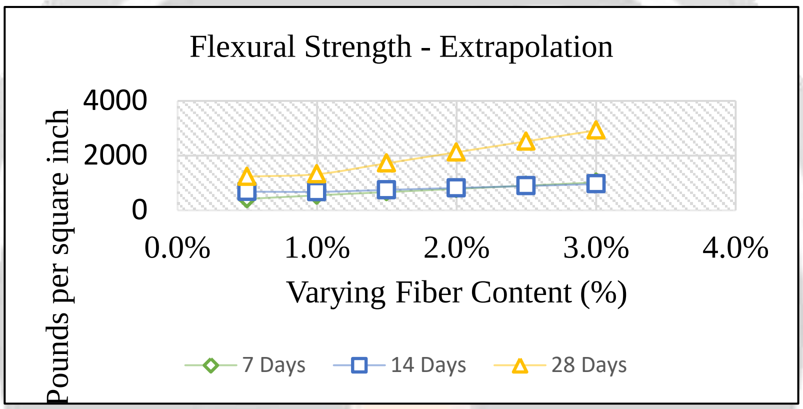

Chart -6: Flexural Strength – Extrapolation

The line graph illustrates the relationship between the fiber content level and the flexural strength of the concrete samples at different time intervals. The x-axis represents the varying fiber content levels, ranging from 0.5% to 3%, while the y-axis represents the flexural strength values in pounds per square inch (psi).

The graph displays three distinct lines, each representing the flexural strength results at 7 days, 14 days, and 28 days. The lines connect the data points corresponding to the tested fiber content levels, and the extrapolated values for the fiber content levels of 2%, 2.5%, and 3% are represented as points on the lines beyond the tested range.

The graph demonstrates that increasing the fiber content generally leads to an improvement in the flexural strength of the concrete samples. At each time interval, the flexural strength tends to increase as the fiber content level increases.

Furthermore, the graph visually emphasizes the progression of flexural strength over time. As the duration of curing increases from 7 days to 14 days and then to 28 days, the flexural strength values generally show an upward trend for each fiber content level.

The extrapolated values provide an estimation of the flexural strength for higher fiber content levels, offering insights into the potential performance of the concrete at those levels.

Overall, the line graph effectively visualizes the relationship between fiber content and flexural strength, providing a clear understanding of how varying fiber content levels impact the flexural strength of the concrete samples over time.

Table -22: Significant difference regarding the L-Box and U-Box Test of BFRC

Banana Fiber Reinforced Concrete	F-Value	F-Critical	Decision	Interpretation
Varying Percentage	0.47	9.55	Accept H_o	With No Significant Difference

Since the F-value of 0.47 is less than the F-critical value of 9.55 at 0.05 level of significance, then failed to reject Ho. Therefore, there is no significant difference in addition of banana fiber as a reinforcement in concrete in workability and consistency the mechanical properties such as L-Box and U-Box Testing. These findings were supported by the results of the L-Box and U-Box tests, which showed no significant difference in the workability and consistency of the concrete with banana fiber compared to the control sample.

With that, the study provides evidence that the addition of banana fiber as a reinforcement in concrete does not significantly affect its workability, consistency, or mechanical properties. This could have important implications for the use of banana fiber as a sustainable and cost-effective alternative to traditional reinforcement materials in the construction industry.

4. CONCLUSIONS

In conclusion, this study successfully evaluated and analyzed the mechanical properties of banana fiber-reinforced concrete (BFRC) through a series of comprehensive tests. The main objective of the study was to assess the viability of banana fibers as reinforcement in concrete and understand their impact on its mechanical performance.

Firstly, the study aimed to determine the effect of varying fiber content on the compressive and flexural strength of BFRC. Through extensive testing, it was found that incorporating banana fibers as reinforcement in concrete significantly enhances its mechanical properties. Particularly, BFRC samples with 1% and 1.5% banana fiber content demonstrated higher flexural and compressive strength at both 14 and 28 days compared to the standard concrete. This finding suggests that increasing the banana fiber content is beneficial for improving the strength and durability of the concrete, although it may result in slower early-age strength development.

The second objective focused on analyzing the strength characteristics of BFRC with respect to its curing time. The study revealed that proper curing time, along with appropriate fiber extraction and preparation procedures, is crucial in achieving the desired mechanical properties. By carefully controlling the curing process, the strength of BFRC can be optimized, leading to improved performance in practical applications.

The third objective aimed to assess the workability and consistency of BFRC mixtures using the L-Box and U-Box tests. The results indicated that all samples exhibited poor passing ability, but the U-Box test further differentiated them. Samples A and B demonstrated good flowability, while sample C exhibited inadequate flowability and a risk of blockage. These findings highlight the importance of considering the workability and flow properties of BFRC when designing concrete mixtures for construction projects.

In summary, this research has established the viability of banana fibers as an effective and sustainable alternative for concrete reinforcement. By utilizing banana fibers in proportions up to 1.5% by weight of the binder, the mechanical performance of BFRC can be optimized. These findings contribute to the understanding and application of BFRC as an environmentally-friendly construction material. The study provides valuable insights for enhancing the quality and performance of BFRC, promoting sustainable construction practices, and presenting cost-effective and recyclable solutions for the industry's future development.

Overall, this study successfully achieved its specific objectives and provides a solid foundation for further research and practical implementation of BFRC in construction projects.

5. ACKNOWLEDGEMENT

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