iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** VI **Month of publication:** June 2023

DOI: https://doi.org/10.22214/ijraset.2023.54493

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Banana Fiber Reinforced Concrete

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Abstract: Over the years because of the expanding natural concerns, bio composite produced out of regular fiber and is one of the latest progress in the business and constitutes the present extent of experimental work. Fiber reinforced composites has numerous preferences, for example, generally minimal effort in creation, simple to create and better quality contrast than perfect polymer tars due with this reason fiber strengthened composite utilized within an assortment of provision as class of structure material. These natural fibers have excellent physical and mechanical properties and can be used more effectively. They are economical, with no chemicals. The addition of and banana fibres significantly improved many of the engineering properties of the concrete notably compressive strength, tensile strength. The ability to resist cracking and spalling were also enhanced. Thus it acts as a natural admixture giving additional properties to the ordinary cement concrete. In this context four different percentages of banana fibres (0.5%, 1%, 1.5%, 2%) having 50mm length were used. M30 concrete and Ordinary Portland cement of grade 43 was used. The and banana fiber reinforced concrete are tested for compressive strength, splitting tensile strength and flexural strength at different ages (7days 14days and 28 days). This work describe the mechanical behavior of banana fiber reinforced polymer composite with the good references to the impact of fiber loading and on the properties of composites.

I. INTRODUCTION

A. Introduction

Although the market for fiber-reinforced concrete is still small compared to total concrete production, the annual global consumption of fibers used in concrete is 300,000 tons. Concrete that contains cement, water, aggregates and discontinuous discrete fibers is called fiber reinforced concrete. The fibers can be in the form of banana fiber, steel fiber, glass fiber, natural fiber, synthetic fiber etc. The fibers are used to reduce shrinkage cracking. The main role of the fibers is to join the cracks that develop in the concrete and increase the ductility of the concrete elements, improving the behavior after the cracking of the concrete. It increases the resistance to the impact load, controls the cracking by plastic shrinkage and cracking by shrinkage by drying and decreases the permeability of the concrete matrix and, therefore, reduces water bleeding. Fiber improves the strength of concrete. Hardness is the ability of a material to absorb the energy and deform plastically without fracturing. It can also be defined as resistance to fracture of a material when stressed. Fibers offer several advantages of steel bars and wire mesh to reduce shrinkage cracks. The fibers are less sensitive to corrosion than reinforcing steel bars and the fibers can reduce the labor cost of placing the bars and the wire mesh. Banana fiber reinforced concrete have been used for making roof tiles, corrugated sheets, pipes, tanks etc. Concrete made with Portland cement has certain characteristics; it is strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bar reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers. The use of fibers also alters the behavior of the fiber-matrix composite after it has cracked. The aim of this research is to experiment on the use of banana fibers as an enhancement of concrete. This research describes experimental studies on the use of banana fiber to enhance the strength and applications of concrete. These natural fibers have excellent physical and mechanical properties and can be used more effectively. They are economical without chemicals. The addition of banana fibers significantly improved many of the engineering properties of the concrete compressive strength, tensile strength and flexural strength. Concrete reinforced with banana fiber has been used for shingles, corrugated sheets, pipes, silos and tanks. Concrete made with Portland cement has some characteristics; It is strong in compression but in weak tension and tends to be fragile. The weakness in tension can be overcome by the use of steel bar reinforcement and, by including a sufficient volume of certain fibers. The use of fibers also alters the behavior of the fiber-matrix composite after it has cracked. The objective of this research is to experiment on the use of banana fibers as an improvement in concrete. This research describes experimental studies on the use of banana fiber to increase the strength and applications of concrete. These natural fibers have excellent physical and mechanical properties and can be used more effectively.

They are economical with no chemicals. The addition of banana fibers majorly improved many of the engineering properties of concrete compression strength, tensile strength and flexural strength.

B. Objective Of The Study

Objectives of the present study are presented as follows:

1) To compare the mechanical properties of Conventional Concrete and BFRC.
2) To evaluate the mechanical properties such as Compressive, Split Tensile strength and Flexural strength of the Banana Fabricated Concrete.
3) To evaluate the Concrete with varied percentages of BFRC and concrete with constant age are compared.

C. Purpose Of The Study

Over 10 million hectares of Banana plantation, with an average of 1500 plants per hectare, exist in more than 160 countries globally, creating tons of banana waste, which have been left over to decompose, emitting a huge amount of methane gas and carbon dioxide. These emissions have a negative impact on the environment, which increases global warming every year. Every ton of banana waste emits, on average, a half-ton of carbon dioxide per year.

This kind of waste has a greater chance of being utilized for different application in construction and building materials. The addition of banana fibres can significantly improve many of the engineering properties of the concrete notably compressive strength, tensile strength and flexural strength. They are economical (zero cost), with no chemicals environmentally friendly and sustainable alternatives from unutilized waste (i.e., banana fibers).

II. LITERATURE REVIEW

A. Literature Review

1) S.M. Sapuan (et.al), 2006, Mechanical properties of woven banana fibre reinforced epoxy composites, Materials.

In this study on analyzing the mechanical properties of woven banana fiber reinforced epoxy composite through flexural and tensile stress test in x and y direction it showed enhanced results. From the results obtained, it was found that the maximum value of stress in x-direction is 14.14MN/m²; meanwhile the maximum value of stress in y-direction is 3.39MN/m². For the Young’s modulus, the value of 0.976GN/m² in x-direction and 0.863GN/m2 in y-direction were computed. As for the case of three-point bending (flexural), The maximum load applied is 36.25N to get the deflection of woven banana fiber specimen beam of 0. 5mm.The maximum stress and Young’s modulus in x-direction recorded to be 26.181MN/m²and 2.685GN/m²respectively.The study neglected the moisture absorption quality of fibers.

2) Samrat Mukhopadhyay (et.al), 2008, Banana Fibers Variability and Fracture Behavior‖ Journal of Engineered Fibers Fabrics.

In this study on analyzing the effect of various diameter of banana fibers chosen randomly within the range of variation of diameter starting from 0.08mm to 0.32m. Based on a class interval of 0.029 mm, which establishes that the standard deviation has decreased with an increase of diameter of the fibers meaning that courser fibers were more regular in nature. The majority of the fibers, as evident from come in the diameter range of 0.17mm to 0.19mm. Hence such fibers were chosen for tensile testing and it was revealed that strain rates played on important role in the nature of the stress strain curve, the strength of the fibers and the nature of failure.

3) Leena Herrera-Estrada (et.al), 2008, Banana fibre composites for automotive and transportation applications.

In this study on investigating the banana fiber reinforced composite material with a thermoset (suitable for automotive and transportation industry) by surface chemical modification and treatments along the processing condition for epoxy and Banana fiber composite flexure test revealed higher values and modulus due to improved fiber matrix interaction. Alkaline fiber composites resulted lower values of compressive and flexural strength as compared to alkaline sample. The resulting banana fiber composites were found to yield a flexural strength of 33.49MPA and compressive strength of 122.11MPA when alkaline pretreated, with improved environment exposure resistance.

While the non alkaline pretreated banana fiber composites were found to yield a flexural strength of 40.16MPA and compressive strength of 123.28MPA.

4) *N. Venkateshwaran (et.al), 2010, Banana Fiber Reinforced Cement Concrete A review Journal of Reinforced Fiber and Composits.*

In his study he reviewed banana fiber reinforced polymer composite. This paper presents a summary of research work published in the field of banana fiber reinforced polymer composites with special references to the structure, physical and mechanical properties of the composites. Due to low density higher tensile strength, high tensile modules and low elongation at break of banana fibers therefore possessing very good potential use in construction, automotive industry etc.

5) *Satish Pujari (et.al), 2014, Comparison of Jute and Banana Fiber Composites .*

In this study he reviewed on the comparison of jute & and banana fiber composites. This review explores the potentiality of jute & banana fiber composites, emphasizes both mechanical and physical properties and their chemical composition. The utilization and application of the cheaper goods in high performance application is possible with the help of this composite technique. He combined the useful properties of the two which resulted in cheaper manufacturing cost, versatility etc. to make them useful in various field of engineering.

6) *D. Chandramohan (et.al), August 2011, A review On natural fibers.*

This study investigates the strength behavior of concrete reinforced with banana fibres to improve the strength and practices of concrete.

Banana plant (Scientific name: Musa acuminate) not only produces the delicious fruit but it also provides the textile fibre. This paper mainly focuses the banana fibre based composites which have wide applications in construction. These banana fibres have good physical and mechanical properties and can be employed more productively.

Banana fibres are economical, ecological and perishable. In this investigation, six different percentages of banana fibres 1%, 2%, 3%, 4%, 5% and 6%) having 40mm length was used.

Ordinary Portland cement of grade 53 and M30 grade concrete were used. At various periodical ages, the banana fibre reinforced concrete is tested for compressive strength, split tensile strength, UPV test.

7) *K. Chandramouli (et.al), March 2019, Experimental Investigation on Banana Fibre Reinforced Concrete with Conventional Concrete.*

Banana fibre reinforced concrete is high performance fibre reinforced concrete with significant behavior under tension. In this paper, examines the strength behavior of concrete reinforced with banana fibres. Banana plant (Scientific name: Musa acuminate) not only produces the delicious fruit but it also provides the textile fibre. This paper mainly focuses the banana fibre based composites which have wide applications in construction.

These banana fibres have good physical and mechanical properties and can be employed more productively. Banana fibres are economical, ecological and perishable. Emphasis is placed on the influence of fibre content on the key micromechanics properties relevant to composite ductility.

In this investigation, six different percentages of banana fibres 1%, 2%, 3%, 4%, 5% and 6%) having 40mm length was used. Ordinary Portland cement of grade 53 and M30 grade concrete were used. At various periodical ages, the BFRC is tested for compressive strength and split tensile strength.

8) *J. Sree Naga Chaitanya,(et.al), August 2022, Strength Study on Comparative of Banana Fibre Reinforced Concrete with Normal Concrete*

In order to increase the strength and practices of concrete, this study examines the strength behaviour of concrete reinforced with banana fibres. The banana plant, scientifically known as Musa acuminate, not only yields the delectable fruit but also the textile fibre.

This essay mostly examines the composites made from banana fibre have several uses in building. The fibres from bananas possess good mechanical and physical qualities and can be used more effectively. Banana leaves are affordable, sustainable, and perishable. Six different banana content percentages were examined in this study.40mm-long fibres (1%, 2%, 3%, 4%, 5%, and 6%) were utilized. Common Portland cement is made of Concrete of grades M30. The banana fibre strengthened the fabric at different ages. Concrete is evaluated for split tensile and compressive strength.

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Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

III. METHODOLOGY

The methodology of the present study is summarized below:

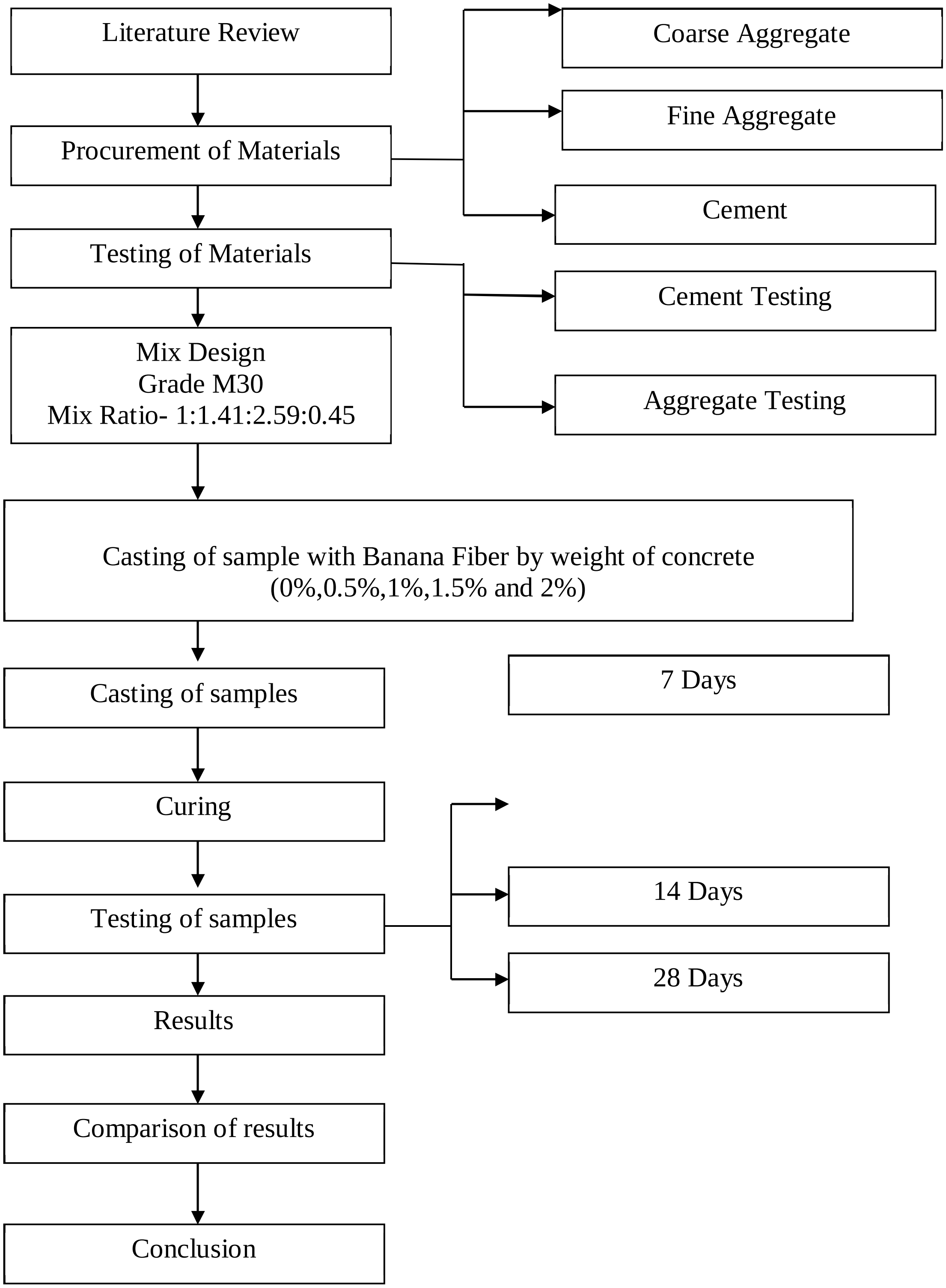

Fig 1.1

Fig. 3.1 Fl ow chart describing methodology of study

The Flowchart of the methodology adopted for the study. All the work mentioned is carried out in the same manner as shown in above flowchart.

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Study of Literature Review for material requirements and observation. Procurement of the material to be used in preparation of the concrete mix i.e. Cement (43 OPC grade), Coarse Aggregate (locally available), Fine Aggregate (locally available) and Banana fiber was done. Number of tests were conducted on the cement and aggregates.Casting of test sample blocks.compression Test Blocks (150x150x150) mm Weighing of material was done followed by manual mixing and finally 9 cubes (3+3+3) were casted each for conventional concrete (0%),0.5%,1%,1.5% and 2% to get the result for 7days,14 days and 28day.Split-Tensile Test Cylinder Weighing of material was done followed by manual mixing and finally 8 Cylinders (2+2) are casted each for conventional concrete (0%) ,0.5%,1% and 2% to get the result for 7days and 28day. Flexural Strength Test Weighing of material was done followed by manual mixing and finally 8 Beam are casted each for conventional concrete (0%) ,0.5%,1% and 2% to get the result for 28day. Tested the sample after drying it for 1 day in Compression Testing Machine (CTM). From the result obtained, tables were made to get the averages from the two values and finally Bar Graphs for pictorial comparison were obtained.

IV. EXPERIMENTAL STUDY

A. Materials

The materials used commonly available Coarse aggregates, fine aggregates, type I Ordinary Portland Cement (OPC), and banana fibers. The fiber is “stick-like” with an embossed surface to create deformations that provide mechanical anchorage. The lengths of the banana fibers were 50 mm cut from full-length fibers.

1) Banana Fibers

Banana fibers are generally lignocelluloses material, consisting of helically wound cellulose micro- fibrils in amorphous matrix of lignin and hemicelluloses. The cellulose content serves as a deciding factor for mechanical properties along with micro fibril-angle. A high cellulose content and low micro-fibril angle impart desirable mechanical properties for banana fibers. Lignin are associated with the hemicelluloses and play an important role in the natural decay resistance of the lignocelluloses materials.

Table 4.1 Composition of studied banana trunk fibers

Constituent	Percentage
Cellulose	64-65%
Lignin	21%
Extractives	7%
Ashes	9%
Moisture	0%

Fig. 4.1 Banana Fiber

2) Cement

A cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. OPC of 43 grades available in local market was used. Cement must develop the appropriate strength. It must represent the appropriate rheological behavior. Generally same types of cements have quite different rheological and strength characteristics, particularly when used in combination with admixtures and supplementary cementing materials.

3) Coarse Aggregate

As coarse aggregates in concrete occupy 35 to70% of the volume of the concrete. It may be proper to categories the properties into two groups: exterior features (maximum size, particle shape, textures) and interior quality (strength, density, porosity, hardness, elastic modulus, chemical mineral composition etc.). Smaller sized aggregates produce higher concrete strength. Particle shape and texture affect the workability of fresh concrete. The transition zone between cement paste and coarse aggregates, rather than the properties of the coarse aggregates itself. Locally available coarse aggregate having the maximum size of 20 mm and FM of 7.04 is used. The specific gravity of coarse aggregate that was taken was 2.7.

4) Fine Aggregate

Fine aggregate normally consists of natural, crushed, or manufactured sand. Natural sand is the usual component for normal weight concrete. In some cases, manufactured light weight particles used for lightweight concrete and mortar. The maximum grain size and size distribution of the fine aggregate depends on the type of product being made. The sand sieved through 4.75mm sieve and retained on 1.18 mm sieve is used having specific gravity of 2.6 a FM of 2.7.

Fig.4.2 It shows materials (a) Fine aggregate (b) Coarse aggregate (c) Cement

5) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Water cement ratio used in the mix is 0.45 for BFRC.

B. Test Performed

1) Tests Performed On Cement

a) Fineness Test Of Cement

Objective: Determination of fineness of cement by dry sieving.

Reference: IS 4031 (Part-1):1988.

Fineness Test on Cement is carried out to check proper grinding of cement. Fineness of cement particles may be determined either by sieve test. In sieve test, the cement weighing 100 gm is taken and it is continuously passed for 15 minutes through standard BIS sieve no. 9. The residue is then weighed and this weight should not be more than 10 per cent of original weight. When the results differ by more than 1 percent absolute, carry out a third sieving and calculate the mean of the three values.

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Fig. 4.3 Determination of fineness of cement by dry sieving.

b) Normal Consistency Test

Objective: Determination of percentage of water by weight of cement required to prepare a standard acceptable (consistent) cement paste.

Reference: IS 4031 (Part-4):1988.

The Consistency of cement test is performed to determine the amount of water content that is to be added in cement to attain Standard consistency or normal consistency of cement. When water is mixed with cement, it starts hydration. Excessive addition of water in cement results an increase in Water cement ratio & ultimately cement loses its strength when it hardens. If Less water is added than required, Cement isn't properly hydrated and results in loss of strength. The Standard or Normal consistency for Ordinary Portland cement varies between 25-35%. To prepare a mix of cement paste of Standard consistency 25-35% of water is added to cement.

Fig. 4.4 Vicat Apparatus with Mould penetrates to a depth 5 to 7 mm from the bottom of the Vicat mould.

c) Initial And Final Setting Time Of Cement

Objective: Determination of initial and final setting time of cement and determine whether the values satisfy IS standards.

Reference: IS 4031 (Part-5):1988

Cement is widely used material in building construction for making cement mortar and concrete. As we know that cement start hydrates when it is mixed with water. In presence of water, cement has a property to achieve strength and get hardened within a short period. So its mandate to place the cement in position without losing its plasticity. To achieve this, the setting time of cement is calculated. Initial Setting time of Cement:- The time to which cement can be moulded in any desired shape without losing it strength is called Initial setting time of cement.

Final setting time of Cement:- The time at which cement completely loses its plasticity and became hard is a final setting time of cement.

2) Tests Performed On Aggregates

1) Fineness Modulus Of Coarse & Fine Aggregates

Objective: To determine fineness modulus and grade of fine and coarse aggregate
Reference: IS: 383-1970.

a) Fineness Modulus Of Coarse Aggregates

Fineness modulus of coarse aggregates represents the average size of the particles in the coarse aggregate by an index number. It is calculated by performing sieve analysis with standard sieves.The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate. Higher the aggregate size higher the Fineness modulus hence fineness modulus of coarse aggregate is higher than fine aggregate. Coarse aggregate means the aggregate which is retained on 4.75mm sieve when it is sieved through 4.75mm. To find fineness modulus of coarse aggregate we need sieve sizes of 80mm, 40mm, 20mm,10mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm.Fineness modulus is the number at which the average size of particle is known when we counted from lower order sieve size to higher order sieve. So, in the calculation of coarse aggregate we need all sizes of sieve.

b) Fineness Modulus Of Fine Aggregates

Fineness modulus of fine aggregate is an index number which represents the mean size of the particles in fine aggregate. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate.Fine aggregate means the aggregate which passes through 4.75mm sieve. To find the fineness modulus of fine aggregate we need sieve sizes of 4.75mm, 2.36mm,1.18mm,0.6mm,0.3mm and 0.15mm.Fineness modulus of finer aggregate is lower than fineness modulus of coarse aggregate.

2) Specific Gravity Of Fine Aggregate

Objective: To determine specific gravity of fine aggregate.
Reference: IS: 2386 (Part-3)-1963.
Fine aggregate is used in many fields in sites for many purposes.So the determination of specific gravity of fine aggregate is very essential. Specific gravity of fine aggregate can be defined as the ratio of the weight of given volume of coarse aggregate to the weight of given volume of distilled water.Clean the pycnometer, dry it, Find the weight of the pycnometer. Take about 200gm of coarse aggregate sample in the pycnometer.Weight the pycnometer, Note the weight W2 Fill the remaining part of pycnometer with distilled water and weight W3 Empty the pycnometer and clean it and fill it with distilled water.Note the weight W4.

Fig. 4.5 Pycnometer being weighed

C. Test Performed On Concrete

1) Workability Test (Slump Test)

Objective: To determine the workability of freshly mixed concrete by the use of slump test.
Reference: IS: 7320-1974, IS: 1199-1959, SP: 23-1982.
Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

The slump test is the most simple workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922. Generally concrete slump value is used to find the workability, which indicates water-cement ratio, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value.

2) Compressive Strength Test

Objective: To determine the cube strength of the concrete of given properties.

Reference: IS: 516 - 1959, IS: 1199-1959, SP: 23-1982, IS: 10086-1982.

To calculate the compressive strength of concrete cubes the universal testing machine (UTM) having capacity of 300 tonne was used. In this test the strength obtained in tonne. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest N/mm2 Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days curing, 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. Calculations

Compressive strength = Maximum load/ Area = $\frac{P}{A}$

Fig. 4.6 Determining the compressive strength of the cube through CTM

3) Split Tensile Strength Test

Objective: To determine splitting tensile strength of cylindrical concrete specimens.

Reference: IS: 5816 - 1999, IS: 1199-1959, SP: 23-1982, IS: 10086-1982.

As we know that the concrete is weak in tension.Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The usefulness of the splitting cube test for assessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen takes place shall then be recorded. The universal testing machine (UTM) having capacity of 150tonne was used for The splitting tensile strength of the concrete cylinders.Calculations:The split tensile strength of the specimen calculated from the following formula

$$Tsp = \frac{2P}{\pi dL}$$

Where P= maximum load in tonne L= length of the specimen d= diameter of width of the specimen

Fig. 4.7 Determining the split tensile strength of the cylinder's through CTM

4) Flexural Strength Test

Objective: To determine flexural strength of cubic concrete specimens.

Reference: IS: 516 - 1959, IS: 1199-1959, SP: 23-1982, IS: 10086-1982.

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. When concrete is subjected to bending, tensile and bending compressive stresses and in many cases, direct shear stresses are developed. The most common plain concrete structure subjected to flexure is a highway pavement and the strength of concrete for pavements is commonly evaluated by means of bending test. Flexural test intended to give the flexural strength of concrete in tension. The flexural test is also more easily carried out and may even be more convenient than the crushing test use in field, since in this test much smaller loads are required.

Fig. 4.8 Determining the flexural strength of the beam through ASTM

V. RESULTS AND DISCUSSION

The results from the analysis of the prepared samples have been compiled below.The results obtained from testing of materials used in a design mix of M30 concrete respectively. Mechanical properties of compressive, split tensile, and flexural strengths of Plain concrete (i.e. without fibres) and Banana Fibre-Reinforced Concrete (BFRC) mixes were determined, and the results are presented below.

1) Determination of Fineness of Cement by dry sieving [IS : 4031 (Part 1) – 1988]

Apparatus Used : Sieve 90 microns
Weight of Cement = 100gm
Result = 9.5% Retained

The given sample of cement contains less than/ more than 10% by weight of material coarser than 90 micron sieve. Therefore it satisfies/ not satisfies the criterion as specified by IS code.

2) Determination of Consistency of Standard Cement Paste [IS : 4031 (Part 4) – 1988]

Apparatus Used :Vicat Apparatus Weight of Cement = 400gm
Result:
Percentage of water required to achieve normal consistency of cement paste is 30 %.

3) Determination of Setting Time of Standard Cement

Paste [IS : 4031(Part 4) -1988, IS : 4031 (Part 5) – 1988]
Apparatus Used :Vicat Apparatus Weight of Cement = 400gm Normal Consistency of a given sample of cement = 30%
Volume of water addend for preparation of test block = 0.85P
= 0.85*120 = 102ml.

A. Results

The given sample of cement satisfied criterion for initial setting time.
The given sample of cement satisfied criterion for final setting time

Table 5.1 Result obtained from testing on cement

S.No	Test	Result	Standard Results as per IS codes
1	Fineness of Cement	9.5% retained on sieve.	Not more than 10% (IS:4031 (PART-1) 1996)
2	Normal Consistency test.	30% normal consistency.	5-7 mm penetration from the bottom (IS:4031 (PART-4) 1988)
3	Initial & Final Setting Time test	IST 56 minutes FST 9hrs 50min	Initial: not less than 30 min (IS:4031 (PART-5) 1988) Final : not more than 10 hrs

B. Aggregates

Fineness Modulus Of Coarse Aggregate
Weight of aggregate taken = 5 kg

Table 5.2 Results obtained from testing on coarse aggregate

Sieve	Material Retained	% Retained	% Cumulative Retained
80	0	0	0
40	0	0	0
20	109	5.45	5.45
10	208	60.4	65.85
4.75	617	30.85	96.70
2.36	43	2.15	98.85
1.18	6	0.3	99.15
600	0	0	99.15
300	0	0	99.15
150	0	0	99.15
		Total	663.45

Result: Fineness modulus of coarse aggregates = 704.16 / 100 = 7.04.Fineness modulus of coarse aggregate varies from 5.5 to 8.0

Fineness Modulus Of Fine Aggregate
Weight of aggregate taken = 5 kg

Table 5.3 Results obtained from testing on fine aggregate

SIEVE SIZE	MATERIAL RETAINED	% RETAINED	CUMULATIVE % RETAINED	% FINER	ZONE
4.75 mm	0	0	0	100	
2.36 mm	100	10	10	90	I
1.18 mm	283	28.3	38.30	61.7	II
600 µ	131	13.1	51.40	48.60	II
300 µ	192	19.2	70.60	29.40	II
150 µ	122	12.2	82.80	17.20	I

Result: Fineness modulus of fine aggregates =253/100 = 2.5 .From IS 383:1970 from table 4, we found aggregates belong to Zone II.

C. Concrete

1) Compressive Strength

To calculate the compressive strength of concrete cubes the universal testing machine (UTM) having capacity of 300tonne was used. In this test the strength obtained in tonne. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest N/mm^2.

Table 5.4 Compressive strength obtained from cube blocks prepared for 7 days curing period.

Banana Fibre%	Block 1	Block 2	Block 3	Average
Conventional Concrete(0%)	19.55	20.07	21.4	20.34
0.5%	23.5	26.2	24.44	24.7
1%	16.88	19.11	23.55	19.84
1.5%	18.90	19.60	20.01	19.50
2%	19.52	18.30	19.30	19.04

Table 5.5 Compressive strength obtained from cube blocks prepared for 14 days curing period.

Banana Fibre(%)	Block 1	Block 2	Block 3	Average
Conventional Concrete(0%)	24.60	26.60	28.06	26.40
0.5%	30.22	29.77	31.55	30.51
1%	24.00	23.50	24.40	23.96
1.5%	21.77	21.33	20.88	21.32
2%	20.00	21.70	22.20	21.30

Fig.5.1 Determining the compressive strength of the cube through CTM for 28 days

Table 5.6 Compressive strength obtained from cube blocks prepared for 28 days curing period.

Banana Fibre(%)	Block 1	Block 2	Block 3	Average
Conventional Concrete(0%)	32.55	33.00	34.20	33.25
0.5%	39.11	37.33	36.88	37.77
1%	33.22	32.20	32.56	32.66
1.5%	32.05	31.33	32.70	32.02
2%	33.56	32.25	30.21	32.00

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

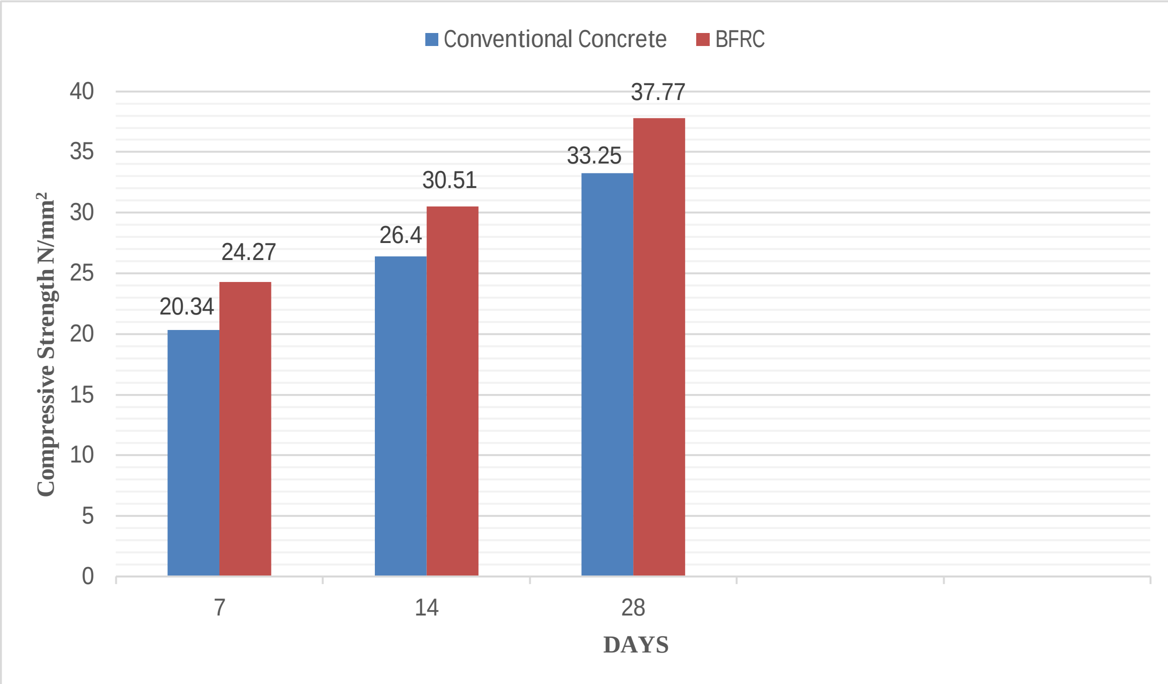

Fig. 5.2 To compare the compressive strength of the conventional concrete and BFRC with constant age.

The Bar Graphs made from the results of compressive tests performed on cubes showed that the values of the compressive strength increased from 0% to 0.5% content of banana fibers by weight of Aggregate. But after 0.5% fiber content the strength decreases because of the difficulty in compaction which ultimately leads to formation of voids.

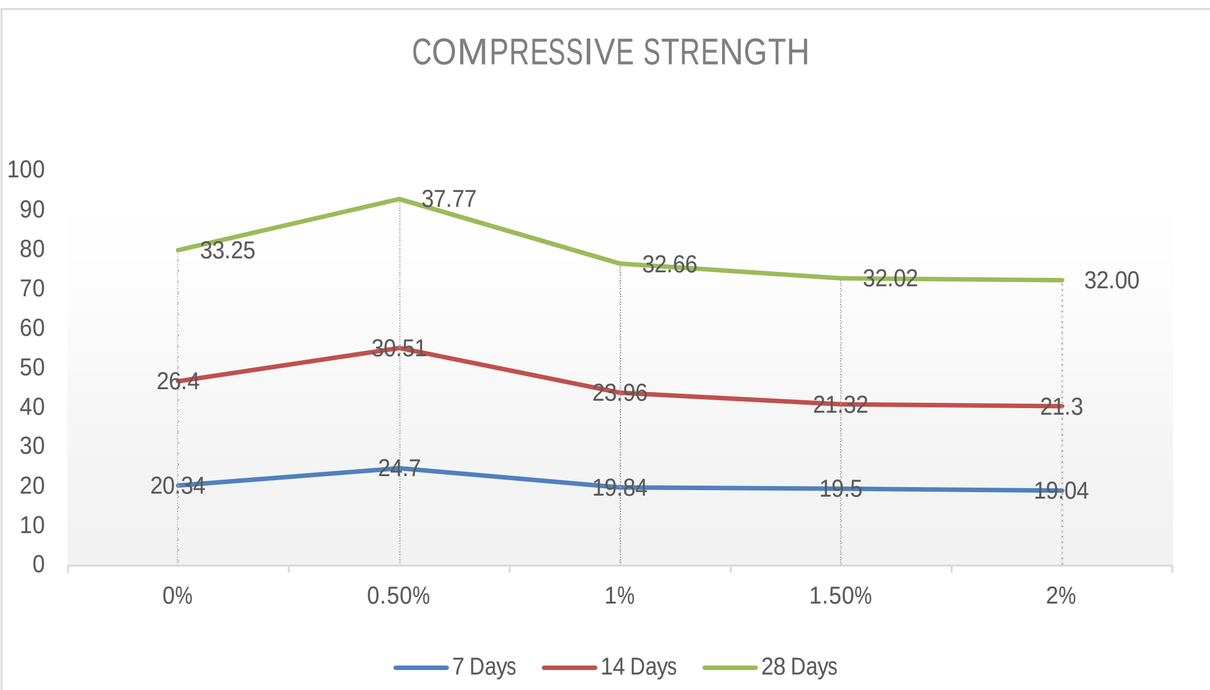

Fig 5.3 To compare the Compressive Strength of BFRC with varied percentages with constant age.

The maximum compressive strength obtained at 0.5% fiber content is 37.77 N/mm2 which is higher than the different percentages of BFRC with constant age. .

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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D. Split Tensile Strength

Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.

Table 5.7 Split Tensile strength obtained for cylinder prepared for 7 days curing period

Banana Fibre(%)	Cylinder 1	Cylinder 2	Average
Conventional Concrete(0%)	2.83	2.67	2.76
0.5%	2,96	2.98	2.97
1%	1.98	2.68	2.33
2%	1.69	2.52	2.10

Table 5.8 Split Tensile strength obtained for cylinder prepared for 28 days curing period

Banana Fibre(%)	**Cylinder 1**	**Cylinder 2**	**Average**
Conventional Concrete(0%)	2.97	3.02	2.99
0.5%	3.52	2.98	3.24
1%	3.28	3.00	3.14
2%	2.96	3.10	3.03

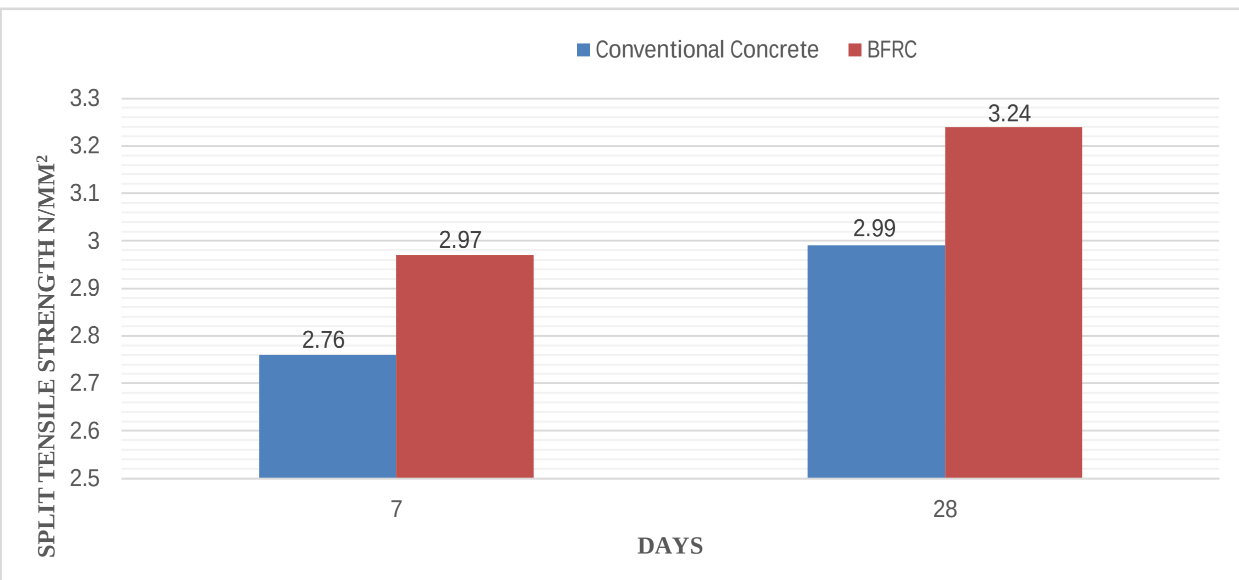

Fig 5.4 To compare the Split Tensile Strength of the conventional concrete and BFRC with varied percentages with constant age.

The Bar Graphs made from the results of split tensile tests performed on cylinders showed that the values of the split-tensile strength increased from 0% to 0.5% content of banana fibers by weight of Aggregate. But after 0.5% fiber content the strength decreases.because of the difficulty in compaction which ultimately leads to formation of voids.

Fig.5.5 Determining the split tensile strength of the cylinder's through CTM for 7 days

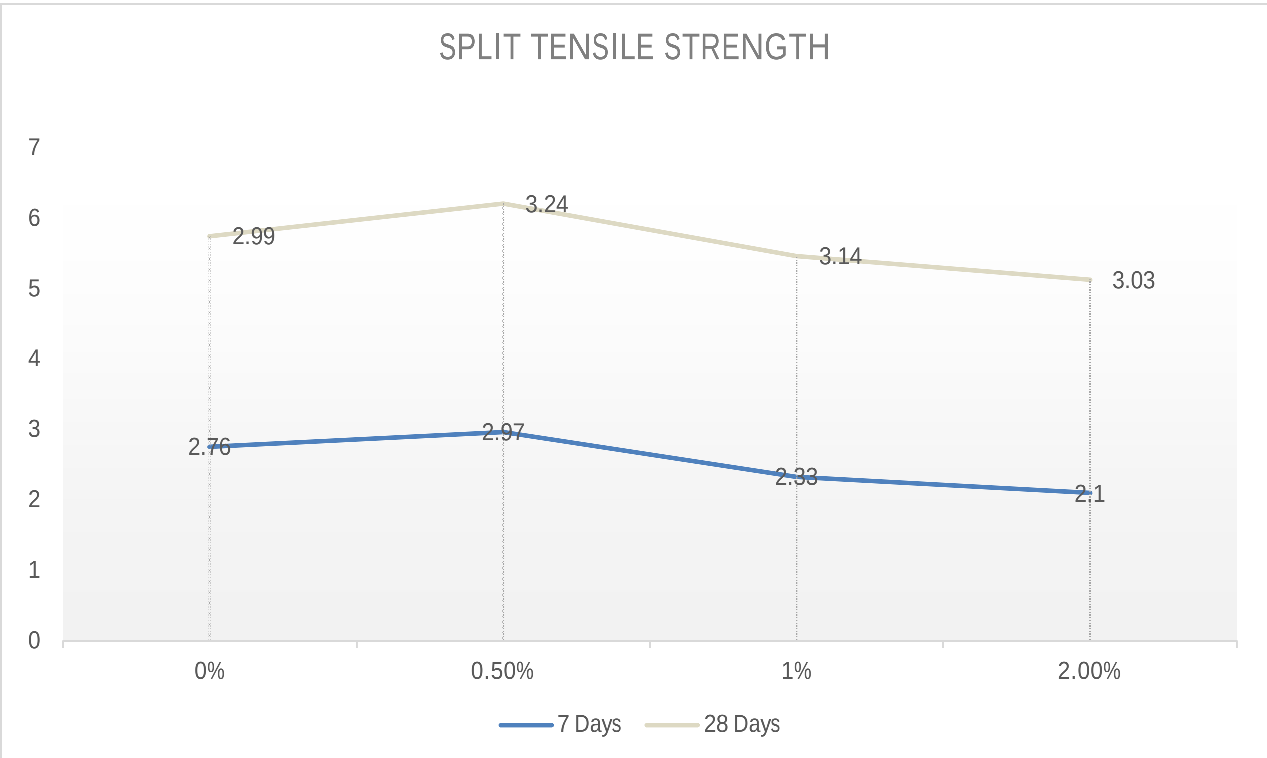

Fig 5.6 To compare the Split Tensile Strength of BFRC with varied percentages with constant age

The maximum split tensile strength attained at 0.5% fiber content is 3.24 N/mm2, which is higher than the different percentages of BFRC with constant age.

E. Flexural Strength

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6-inch (150 x 150-mm) concrete beams with a span length at least three times the depth.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Table 5.9 Flexural strength obtained for cube blocks prepared for 28 days curing period

Banana Fibre(%)	Beam 1	Beam 2	Average
Conventional Concrete(0%)	3.95	3.65	3.80
0.5%	4.06	4.10	4.08
1%	3.89	4.06	3.97
2%	3.77	3.87	3.87

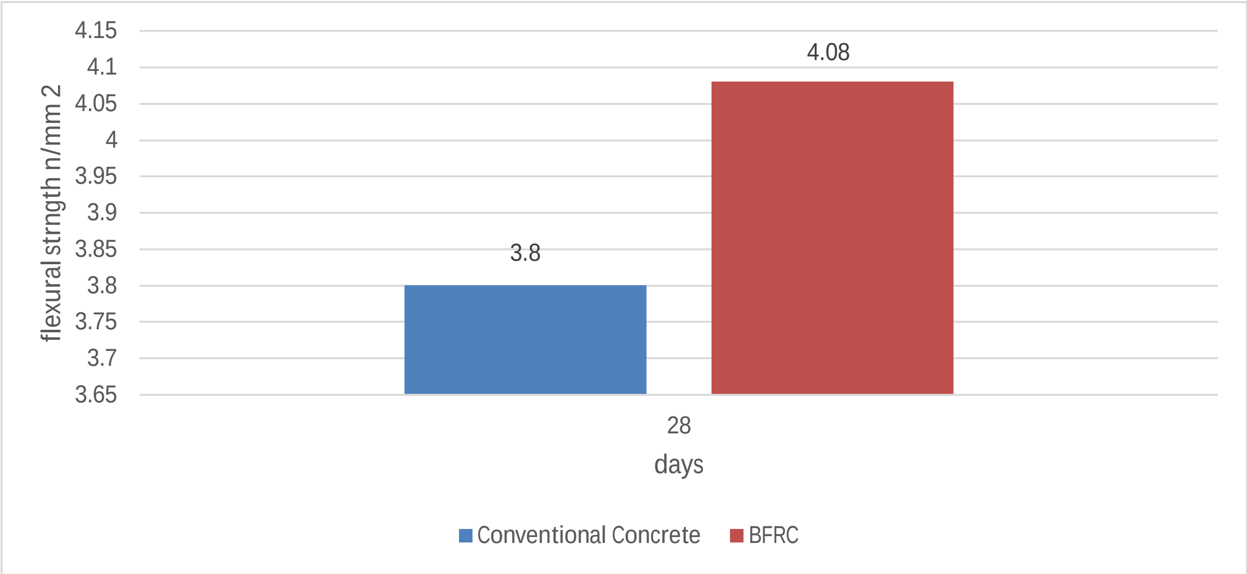

Fig 5.7 To compare the Flexural Strength of the conventional concrete and BFRC with varied percentages with constant age.

The Bar Graphs made from the results of tensile tests performed on Beam showed that the values of the split-tensile strength increased from 0% to 0.5% content of banana fibers by weight of Aggregate. But after 0.5% fiber content the strength decreases because of the difficulty in compaction which ultimately leads to formation of voids.

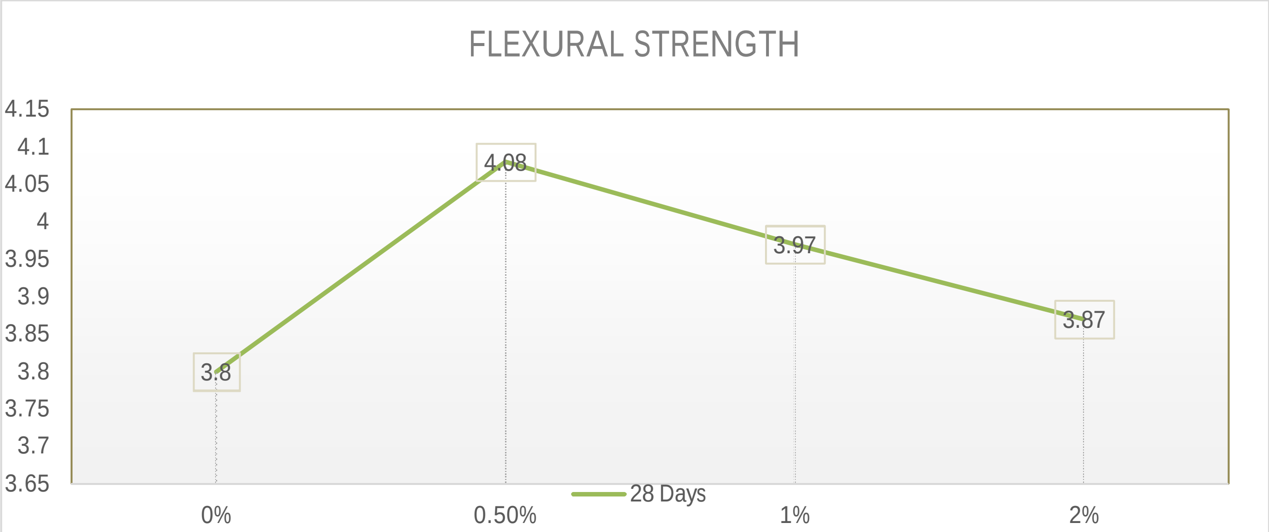

Fig 5.8 To compare the Flexural Strength of BFRC with varied percentages with constant age.

The maximum flexural strength obtained at 0.5% fiber content is 4.08 N/mm2, Which is higher than the different percentages of BFRC with constant age.

VI. CONCLUSIONS

The main objective of this study is to analyze the performance of addition of commercially available Banana fibers as an additive in cementitious materials to improve the mechanical properties of conventional concrete and to enhance the flexibility to resist cracking and spalling of concrete structures.

The addition of banana fibers considerably increased the strength characteristics of concrete, compressive strength, tensile strength and flexural strength.The compressive strength of concrete has increased up to 0.5% addition of banana fibre and has shown decrement in the compressive strength that percentage.The compressive strength obtained at 0.5% fiber content is 37.77 N/mm2 which is 13.59% higher than the reference conventional concrete strength. A reduction in compressive strength is attributed to increase in porosity of the concrete matrix as a result of the addition of fibres, creating large contents of pores and microcracks at the matrix-fibre interface. Furthermore, reduction in compressive strength with increasing fibre content is likely to be associated with the effect of fibres on Interfacial Transition Zones (ITZs) and voids in concrete. It is expected that the more the amount of fibres, the more the ITZs will be created in concrete, which in turn negatively affects the compressive strength.

The maximum split tensile strength attained at 0.5% fiber content is 3.24 N/mm2, which is 7.71% higher than the reference conventional concrete strength .hat addition of fibres had a significant improvement in tensile strength because they slowed down crack propagation, thereby enhancing mechanical strength of concrete.A drop in tensile strength of BFRC beyond 1% of fibre content can be attributed to excessive amount of fibre content in the concrete, which end up having an adverse effect on the strength of concrete as was similarly observed for compressive strength.

The maximum flexural strength obtained at 0.5% fiber content is 4.08 N/mm2, which is 7.36% higher than the reference conventional concrete strength .Addition of banana fibres generally did not greatly contribute to flexural strength of concrete but had a marginal impact only when shorter fibres were used at lower fibre dosages. Contrastingly, the flexural strength of all BFRC mixes containing longer fibres decreased with increasing fibre content.

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[10] IS 456 (2000): Plain and Reinforced Concrete.
[11] IS 10262-(2019): Concrete Mix Proportioning.

APPENDIX

A. Appendix-A

Test On Cement

A.1 Determination of Fineness of Cement by dry sieving [IS : 4031 (Part 1) – 1988]

Apparatus Used : Sieve 90 microns

Weight of Cement = 100gm

Result = 9.5% Retained

Desired Result = Retention < 10%(O.K)

A.2Determination of Consistency of Standard Cement Paste [IS : 4031 (Part 4) – 1988]

Apparatus Used :Vicat Apparatus Weight of Cement = 400gm

Table I Result of normal consistency test

Percentage by water of Dry Cement(%)	Penetration (mm)
27	Full Penetration
29	10mm from bottom
30	6mm from bottom

Desired Result = Penetration (5mm-7mm)

Result = Normal Consistency of a given sample of cement is 30

Determination of Setting Time of Standard Cement
Paste [IS : 4031(Part 4) -1988, IS : 4031 (Part 5) – 1988]

Apparatus Used :Vicat Apparatus Weight of Cement = 400gm Normal Consistency of a given sample of cement = 30%

Volume of water addend for preparation of test block = 0.85P
= 0.85*120 = 102ml.

Results:

Initial Setting Time = 56mins

Final Setting Time = 9hrs 50mins Desired Results:

Initial Setting Time > 30mins

Final Setting Time < 10hrs(O.K)

B. Appendix-B

TEST ON AGGREGATES

FINENESS MODULUS OF COARSE AGGREGATE

Weight of aggregate taken = 5 kg

Table II Result of fine modulus of coarse aggregate

Sieve	Material Retained	% Retained	% Cumulative Retained
80	0	0	0
40	0	0	0
20	109	5.45	5.45
10	208	60.4	65.85

4.75	617	30.85	96.70
2.36	43	2.15	98.85
1.18	6	0.3	99.15
600	0	0	99.15
300	0	0	99.15
150	0	0	99.15
		Total	663.45

Fineness modulus of coarse aggregates = 704.16 / 100 = 7.04

Fineness Modulus Of Fine Aggregate
Weight of aggregate taken = 5 kg

Table III Result of fine modulus of fine aggregate

SIEVE SIZE	MATERIAL RETAINED	% RETAINED	CUMULATIVE % RETAINED	% FINER	ZONE
4.75 mm	0	0	0	100	
2.36 mm	100	10	10	90	I
1.18 mm	283	28.3	38.30	61.7	II
600 µ	131	13.1	51.40	48.60	II
300 µ	192	19.2	70.60	29.40	II
150 µ	122	12.2	82.80	17.20	I

Fineness modulus of fine aggregates =253/100 = 2.53
From IS 383:1970 from table 4, we found aggregates belong to Zone II.

GRADING OF AGGREGATES [IS 383:1970 table 2]

Table IV Grading of aggregates [IS 383:1970 table 2]

Sieve	Net Required for 1 kg	Net Required For 5 kg
20	0	0
16	320 g	1600 g
12.5	202 g	1010 g
10	176 g	880 g
4.75	276 g	1380 g
2.36	18 g	90 g
Pan	8 g	40 g

C. Appendix-C

Procedure Of Design Mix Of M30 Grade Concrete

SPECIFICATION OF MATERIALS:-

1. Characteristic compressive strength required at 28 days grade designation — M 30
2. Nominal maximum size of aggregate — 20 mm
3. Degree of workability required at site — 100 mm (slump)
4. Type of exposure the structure will be subjected to (as defined in IS: 456) — Severe
5. Type of cement: OPC 43 Grade
6. Method of concrete placing: Manual
7. Test data of material (to be determined in the laboratory)

(a) Specific gravity of cement — 3.15
(b) Specific gravity of FA — 2.66
(c) Specific gravity of CA — 2.73
(d) Aggregate are assumed to be in saturated surface dry condition.
(e) Fine aggregates confirm to Zone II of IS – 383

Step 1- Determination Of Target Strength

Himsworth constant for 5% risk factor is 1.65. In this case standard deviation is taken from IS:456 against M 30 is 5.0.

$f_{target} = f_{ck} + 1.65 \times S$

$= 30 + 1.65 \times 5.0 = 38.25\ N/mm^2$

Where, S = standard deviation in N/mm^2 = 5 (as per table -1 of IS 10262- 2009)

Step 2- Selection of water / cement ratio:-

From Table 5 of IS 456, (page no 20)

Maximum water-cement ratio for Moderate exposure condition = 0.45 Based on experience,
adopt water-cement ratio as 0.45. 0.42<0.45 hence ok.

Step 3- Selection of Water Content

From Table 2 of IS 10262- 2009, Maximum water content = 186 Kg (for Nominal maximum size of aggregate — 20 mm).

Table V for Correction in water content

Parameters	Values as per Standard reference condition	Values as per Present Problem	Departure	Correction in Water Content
Slump	75-100mm	75-100	25	(+6/25) x 25 = +6

Estimated water content = 186+ (6/100) x 186 = 197.16 kg /m^3

Step 4: Selection of Cement Content

Water-cement ratio = 0.45

Corrected water content = 197.16 kg /m^3

Cement content = Corrected water content/ Water-cement ratio

= 197.16/0.45

= 438.13 kg/m^3

Step 5: Estimation of Coarse Aggregate proportion:
From table no.3 Volume of C.A corresponding to 20mm size aggregate & Fine aggregate (Zone 2) for W/C ratio of 0.5=0.62.
In present case W/C ratio is 0.45 therefore vol. of course aggregate is required to be increased, to decrease fine aggregate content.
If W/C ratio lowered by 0.05 the proportion of vol. of course aggregate is increased by 0.016 m^3 therefore, corrected proportion of vol. of course aggregate for W/C ratio of 0.45 is 0.636m^3.
Therefore volume of Course aggregate is=0.636X1=0.636
Volume of Fine aggregate is = 1-0.636 = 0.364m^3

Step 6: Calculation of Mix Proportions
Volume of concrete = 1 m^3
Volume of cement = Mass of cement / (Sp. Gravity of cement *1000)
= 438 / (3.15*1000)
= 0.139 m

Volume of water = Mass of water / (Sp. Gravity of water*1000)
= 197.16 / (1*1000)
= 0.197m^3
Volume of chemical admixtures = Nil.
Volume of all in aggregate = [A-(B+C+D)] = [1-(0.01+0.139+0.197)]
= 0.6539 m^3 (say value as **'e'**)
Mass of coarse aggregate = e * vol. of C. A. * Sp. gravity of C. A. * 1000
= 0.6539 * 0.636 * 2.73* 1000
= 1135.5 kg/m^3
G Mass of fine aggregate = e * vol. of F.A. * Sp. gravity of F.A * 1000
= 0.6539 * 0.364* 2.6 * 1000
= 618.85 kg/m^3

Step 7: Quantities of materials
CEMENT = 438 kg/m^3
FINE AGGREGATE = 618.85 kg/m^3
COURSE AGGREGATE = 1135.35 kg/m^3
WATER = 197.16 kg/m^3
WATER CEMENT RATIO = 0.45

Table VI to express proportion in usual way.

CEMENT	FINE AGGREGATES	COARSE AGGREGATE	WATER
1	1.41	2.59	0.45