AN EXPERIMENTAL INVESTIGATION OF THE CONCRETE BY ADDITION OF BAMBOO AS FIBRE

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***Abstract*: For construction, one of the most important materials is concrete. Concrete is preferred because of its Low cost, High strength, Thermal & fire resistance, Availability, Durability, Diversity etc. Concrete cannot be used at places where tensile forces are predominant alone because concrete is known to have low tensile strength. Bamboo is rich in fibre, natural, cheap, easily available and importantly strong enough both in tension and compression. To check the compressive and flexure strength, concrete cubes reinforced with bamboo fibre have been tested by changing the percentage of fibre. Usually M20 concrete is used for most of the constructional works, hence in this project M20 concrete is taken. In this report, effects of material proportion of volume of bamboo fibres on Bamboo Fibre Reinforced Concrete have been examined. Test beams for flexural strength, cubes and cylinders for compressive and splitting strength are cast using ordinary Portland cement and three types of fibre content 0, 1 and 2%.Tests were conducted on coarse aggregates, fine aggregates and cement. Studys were made on bamboo fibre to determine their physical properties. Cubes, cylinders and beams were casted and tested for 7, 14 and 28 day's strength. These tests revealed that the optimum bamboo fibre content was found to be 1% by weight of cement, fine and coarse aggregates.**

Index Terms; Bamboo fibre, Compressive, Flexural Strength split tensile strength

1. INTRODUCTION

Concrete having brittle property with less value of tensile strength and strain capacities, hence is preferred with fibres. Fibre reinforced concrete (FRC) had overcome this problem since 1960s. In past fibres were widely used in many types of mortar and concrete for providing stability. Steel, organic polymers, glass, carbon, asbestos, and cellulose are most commonly used fibres.

Adding fibres to concrete matrix has been long recognized as a way to enhance the energy absorption capacity and crack resistance of the plain concrete, Consideration of toughness and the fracture energy is important since it determines the ductility and crack resistance of the structure assuring the safety and integrity of the structural element prior to its complete failure. Bamboo Fibre shows good potential and increased strength when used in the Fibre reinforced concrete and the fibres acts as a crack resistors, hence take up a lot more load as compared to the conventional concrete.

The mechanical properties of Bamboo in the physical, as well as mechanical properties vary with respect to diameter, length, age, type, position along column, and moisture content of bamboo and studies showed that the ultimate load of a concrete beam reinforced with bamboo increased by 400% as compared to un-reinforced concrete. Also; the thorough investigation into the structure and purposes of the nodes, which they found to be strengthen by the Bamboo fibre.

1.1 ADVANTAGES OF BAMBOO FIBRE CONCRETE

Economical, it has high tensile strength, it is highly flexible, Environment-friendly, it has great shock-absorbing capacity.

1.2 OBJECTIVES

The objectives of this study are as listed below:

- To study the properties of bamboo fibre .
- To study the Compressive strength .
- To study the Flexural strength .
- To study the split tensile strength .

1.3 SCOPE OF WORK

- Concrete is weak in tension and strong in compression .so, To over come this difficulty introduce bamboo fibre in plain concrete to enhance the tensile strength.
- Bamboo is extremely strong natural fibre.
- Low cost and environment-friendly.
- It has high shock absorbing capacity.

2. REVIEW OF LITERATURE

A literature review is a body of text that aims to review the critical points of current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic. Hence an attempt is made in this chapter to review briefly the works carried out by earlier investigators on the study of this topic.

Masakazu TERAI (2012) : Basic Study on Mechanical Properties of Bamboo Fibre Reinforced Concrete: Fibre reinforced concrete is getting popular in the field of construction materials. Study on the use of fibre materials such as asbestos, grass, polyester, rayon, steel and so on, as reinforcement in fibre-reinforced composites is carried out. In this paper, effects of material proportion (volume of bamboo fibres) on Bamboo Fibre Reinforced Concrete have been examined. Test beams for flexural strength and cylinders for compressive and splitting strength are cast using ordinary Portland cement and four types of fibre content (0, 1, 2 and 3%). Results of the experimental investigation to determine the workability (slump and air quantity) and the flexural, compressive and tensile strength of the bamboo fibre reinforced concrete are presented.

N.V. Vamsi Krishna Togati (2012): INVESTIGATION ON PROPERTIES OF BAMBOO AS REINFORCING MATERIAL IN CONCRETE: The indiscriminate infrastructural growth is leading to rapid environmental degradation. Steel, cement, synthetic polymers and metal alloys used for construction activities are energy intensive as well as cause environmental pollution during their entire life cycle. In order to quantify the energy and CO2 savings potential by applying best available technologies like vegetable fibres including bamboo, wastes from industry and mining etc., for engineering applications. In this paper an attempt has been made for finding bamboo as reinforcement in concrete by determining the various physical and mechanical properties of bamboo.

The investigations conducted for the tested types of bamboo are evaluated using the same accept criteria as that of steel.This study investigates the Moso type bamboo tensile stress, compressive stress, Modulus of Elasticity, Water absorption capacity, Shear stress, and bonding stress. In general the strength of bamboo is as high as mild steel while, their density is as low as carbon fibre.

Saiada Fuadi Fancy (2012):Performance Evaluation Of Bamboo Twig As A Potential Reinforcement In Concrete Considering Tensile Property: This research was undertaken to evaluate the aptness of bamboo twig as reinforcement in concrete to compensate the low tensile property of the concrete. Even though steel reinforcement is a very suitable material for complementing concrete's low tensile strength, considering the high cost and general shortage of reinforcing steel in many parts of the world has led to increasing interest in the possible use of alternative locally available materials for the reinforcement of concrete. Since bamboo twig is a natural, cheap and also readily available material, it can be a substitute of steel in reinforcing of concrete. To assess this, tensile strength test of bamboo twig specimen having minimum three knots were performed. From this test, the tensile strength, proof strength and modulus of elasticity were determined from stress-strain curve for bamboo twig reinforcement and satisfactory results were obtained in terms of tensile strength and stress-strain characteristics of bamboo twig for using as reinforcement in the concrete.

Durgesh Kumar Gupta, R. C. Singh (2018) : An Experimental Evaluation of Mechanical Properties of Bamboo Fibre Reinforced Concrete: For construction, one of the most important materials is concrete. Concrete is preferred because of its Low cost, High strength, Thermal & fire resistance, Availability, Durability, Diversity etc. Concrete cannot be used at places where tensile forces are predominant alone because concrete is known to have low tensile strength. Bamboo is rich in fibre, natural, cheap, easily available and importantly strong enough both in tension and compression. To check the compressive and flexure strength, concrete cubes reinforced with bamboo fibre have been tested by changing the percentage of fibre.

Dr. Shakeel Ahmad, Altamash Raza(2014):Mechanical Properties of Bamboo Fibre Reinforced Concrete: Bamboo is one of the oldest building materials used by mankind. The bamboo culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material. In many overly populated regions of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing. With the advancement of science and technology and the good supply of timber, new methods are needed for the processing of bamboo to make it more durable and more usable in terms of building materials.The mechanical properties of Bamboo, specifically pertaining to Bamboo in concrete.

Humberto C. Lima, Normando P. Barbosa(2008): Durability analysis of bamboo as concrete reinforcement: Durability is an actual challenge concerning all construction materials. If these materials are natural, the necessity to understand their long term behaviour is extremely important, because they are considered as having a low capacity to maintain their properties with time. Bamboo is a high strength material that can be used, in certain cases, as reinforcement in concrete. As concrete matrix has a high pH, many authors have discussed the decay of vegetal materials when used to reinforce cementitious matrix. This paper presents results of an experimental investigation made to evaluate bamboo durability to be used as concrete reinforcement. The durability was evaluated by changing the tensile strength and Young's Modulus of bamboo.

3. MATERIALS USED AND THEIR PROPERTIES

- The materials used for this study are given below ,
- Ordinary Portland cement (43 grade)
- Sand (zone 2 as per IS 383:1970)
- Coarse aggregate (as per IS 383:1970)
- Bamboo fibre naturally extracted

3.1 Cement

Ordinary Portland cement of 43 grades available in local market is used in the experiment. The cement used has been tested for various properties and test result are shown in the table

Table 1: Physical properties of OPC 43 grade

S.No	Property	Test result
1	Normal consistency	30%
2	Specific gravity	3.15
3	Setting time Initial setting time Final setting time	 28 min 598 min
4	Fineness of cement	3.5%

Table 2: Chemical composition of cement

s.no	constituent	Percentage (%)
1	Calcium oxide	62
2	Silica	22
3	Al2O3	5
4	Magnesium	1
5	Calcium sulphate	4

3.2 Fine Aggregate

Aggregate which is passed through 4.75 IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Important thing to be considered is that fine aggregates should be free from coagulated lumps. Grading of natural sand or crushed stone i.e. fine aggregates shall be such that not more than 5 percent shall exceed 5 mm in size, not more than 10% shall IS sieve No. 150 not less than 45% or more than 85% shall pass IS sieve No. 1.18 mm and not less than 25% or more than 60% shall pass IS sieve No. 600 micron

Table 3: Properties of fine aggregate

Particulars	Test values
Fineness modulus	6.67
Specific gravity	2.80

3.3 Coarse Aggregate

Coarse aggregate for the works should be river gravel or crushed stone .It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped and should have granular or crystalline or smooth non-powdery surfaces. Aggregates should be properly screened and if necessary washed clean before use. Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications. After 24-hrs immersion in water, a previously dried sample of the coarse aggregate should not gain in weight more than 5%. Aggregates should be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

Table 4: Properties of coarse aggregate

Particulars	Test values
Fineness modulus	6.67
Specific gravity	2.60

3.4 Bamboo Fibre

Bamboo grows in the tropical and subtropical area. Due to the cheaper cost, bamboo houses can be built for people in the world. Because of the successful construction of bamboo houses, companies and researchers has observed for using bamboo as structural element of construction, such as bamboo reinforced concrete. Bamboo plants has the potential to develop of innovation in construction. Several studies have been carried out on the use of raw bamboo as reinforcing material to replace conventional steel. Usually, bamboo was used for construction and home furnishings. Bamboo pieces were used for toothpicks, skewers, and the wicker. This furniture manufacturing process produces waste in the form of bamboo fibre. Therefore, bamboo fibre will be observed for repairing cracks in concrete.

Aspect ratio = length of fibre/dia of fibre
= 100 mm/2mm
= 50mm

Table 5: Properties of bamboo fibres

Particulars	**Test values**
Specific gravity	0.575 to 0.655
Average weight	0.625 kg/m
Modulus of rupture	610 to 1600 kg/cm^2
Modulus of elasticity	1.5 to $2.0x10^5$ kg/cm^2
Ultimate compressive stress	794 to 864 kg/cm^2
Safe working stress in compression	105 kg/cm^2
Safe working stress in tension	160 to 350 kg/cm^2
Safe working stress in shear	115 to 180 kg/cm^2
Bond stress	5.6 kg/cm^2

4. MIX DESIGN

Mix design is a process of specifying the mixture of ingredients required to meet anticipated properties of fresh and hardened concrete. Concrete mix design is a well-established practice around the world. Adapting from developed countries, many developing countries have standardized their concrete mix design methods.

4.1 Procedure for mix design as per IS (10262 : 2009)

1) The following basic data are required for a concrete mix.
   a. Characteristics compressive strength of concrete
   b. Degree of workability desired
   c. Max water cement ratio of coarse aggregate
   d. Type of max size of coarse aggregate
   e. Standard deviation-based on concrete control
   f. Statistical constant-accepted
   g. Grade of cement used
2) Target mean strength is determined by

   a. Fck= fck+ t x s

3) The water/cement ratio for the target mean strength is limited as per table 5 of (IS:456-2000)
4) Appropriate water content per kg of concrete are selected as per table 2 of (IS 10262 : 2009)
5) Adjustment in aggregate percentage and water content are made as per table 3 and by the clause 4.2 of (IS 10262 : 2009)
6) Collected water quantity is computed and hence from W/c ratio.
7) The quantity of fine aggregate and coarse aggregate per unit volume of concrete can be calculated from.
8) Volume of material = (Mass of material / specific gravity of material) X (1/1000)
9) The mix proportions by weight are computed by keeping cement as one unit.

4.2 Data

Characteristic compressive strength required	: 20 N /mm2
Maximum size of aggregate	: 20 mm
Degree of workability	: 0.90 compacting
Degree of quality control	: Good
Type of exposure	: Moderate
Specific gravity of cement	: 3.15
Specific gravity of fine aggregate	: 2.60
Specific gravity of coarse aggregate	: 2.60
Water absorption fine aggregate	: 1 Percent
Water absorption coarse aggregate	: 0.5 Percent
Free (surface) moisture of aggregate	: 2 Percent

4.3 Target mean strength of concrete :

For tolerance factor of 1 .65 and assumed standard deviation
, the target mean strength for specified characteristics cube strength is,
Target mean strength, $F_{ck} = f_{ck} + t \times s$
= 20 + 1.65 x 4
= 26.6 N/mm2

4.4 Selection of water/cement ratio:
The free water/cement ratio required for the target mean strength of is 0.50.This is lower than the maximum value of 0.55 prescribed for mild exposure in Table 5 of IS 456: 2000.

4.5 Selection of water and sand content:
For 20 mm nominal maximum size aggregate and sand conforming to grading zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage to total aggregate by absolute volume = 35 percent.
4.6 Adjustment required if any:
For change in values in water/cement ratio, compacting factor and sand belonging to zone III, the following adjustment is required:

(i) For water content percent:
For decrease in water/cement ratio by (0.60-0.50)
that is 0.10 = 0%
For increase in compacting factor (0.90-0.80)
That is 0.60 = +3%
For sand conforming to zone III of Table 4 of
IS 383 : 1970 = 0%
Total = 3%
Required water content = 186 + 3% of 186
= 186 + 2/100 x 186
= 186 + 5.5
= 191.6 kg/m^3 (or) lit/m^3 (or) $1/m^3$

(ii) For sand in total aggregate :
For decrease in water/cement ratio
By (0.60 – 0.50) that is 0.10 = -2.0%
For increase in compacting factor
(0.90 – 0.80) that is 0.10 = 0%
For sand conforming to zone III of
Table 4 of IS: 383 – 1970 = -1.5%
Total = -3.5%
Therefore, required sand content as percentage of total aggregate by absolute volume = 35 – 3.5 = 31.5 percent.

4.7 Determination of cement content :
Water cement ratio = 0.50
Water = 191.6 litres
Cement = 191.6/0.50 = 383 kg/m^3
This cement content is adequate for mild exposure condition, according to Table 5 of IS 456 : 2000.

4.8 Determination of fine and coarse aggregate content:

For specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 percent. Take this into account and applying equations below,

$$V = [\, W + C/S_C + 1/P \,.\, f_a/S_{fa} \,] \times 1/1000$$
$$V = [\, W + C/S_c + 1/1\text{-}p \,.\, C_a/S_{ca} \,] \times 1/1000$$
$$0.98 = (\, 191.6 + 383/3.15 + 1/0.315 \times f_a/2.60 \,) \times 1/1000$$
$$F_a = 546 \text{ kg/m}^3 \text{ and}$$
$$0.98 = (\, 191.6 + 383/3.15 + 1/1\text{-}0.315 \times C_a/2.60 \,) \times 1/1000$$
$$C_a = 1188 \text{ kg/m}^3$$

4.9 Mix proportion:

From the above steps 1 to 6, the mix proportion then becomes:

Table 6: Mix proportion

Cement	Fine aggregate	Coarse aggregate	Water
383 kg	546 kg	1188 kg	191.60 kg
1	1.42	3.10	0.50

6.4.8 Actual quantities of material required:

(i) Water

For water/cement ratio of 0.50 quantity
of water = 191.60 lit
Add extra quantity of water to be added for absorption in case of coarse aggregate, at 0.50 percent by mass,
0.50/100 x 1188 = +5.94 lit
Deduct quantity of water for free moisture present in sand, at 2 percent by mass
2/100 x 546 = -10.92 lit
Therefore , actual quantity of Water to be added = 186.62 lit

(ii) Fine aggregate

As per original calculation fine aggregate = 546 kg
Add 2 percent for free moisture = 10.92 kg
Actual quantity of sand required after
allowing for mass of free moisture = 556.92 kg

(iii) Coarse aggregate

As per original calculation = 1188 kg
Deduct 0.50% for water absorption,
0.50/100 x 1188 = -5.94 kg
Total aggregate = 1182 kg
Fraction I (60%) = 60/100 x 1182 = 709.20 kg
Fraction II (40%) = 40/100 x 1182 = 472.80 kg

-6.4.9 Actual quantities required for the mix without adjustment:

The mix 1 : 1.42 : 3.10 : 0.50 (by mass), the mix quantity different materials are :
Cement : 383 kg
Sand : 546 kg
Coarse aggregate : 1188 kg (Fraction I = 712.80 kg)
(Fraction II = 475.20 kg)
Water : 191.60 kg

2**6.4.10 Actual quantities required for the mix with adjustment:**
(Ratio: 1 : 1.45 : 3.08 : 0.487)
Cement : 383 kg
Sand : 556.92 kg
Coarse aggregate : 1182 kg (Fraction I = 709.20 kg)
(Fraction II = 472.80 kg)
Water : 186.62 lit

5. TESTS CONDUCTED ON HARDENED CONCRETE
5.1 Compressive strength test

The compressive strength is one of the most important properties of hardened concrete. The test specimens in shape of size 150*150*150mm . Minimum of 3 cubes should be tested. Compression of tests are conducted at 7 days ,14 days and 28 days of the casting of specimens. After completion of curing ,

$$fck = P/A\ (N/mm^2)$$

Where,
P = Load at which the specimen fails in Newton (N)
A = Area over which the load is applied in mm^2.

5.2 Split Tensile strength Test

Tensile strength is one of the most important fundamental properties of concrete. An accurate prediction of tensile strength of concrete will be mitigating cracking problems The split tensile strength was determined at the age of 7 days, 14 days and 28 days on cylinders of sizes 300mm*150mm as per IS specifications BIS516-1959. The magnitude of this tensile stress (acting in a direction perpendicular to the line of action of applied compression) is given by,

$$\text{Tensile stress} = {}^{2p}/_{\pi dl}$$

Where,
P = Applied load at failure in N,
L = length of cylinder in mm
d = Diameter of cylinder in mm

5.3 Flexural strength test on beam

The Flexural strength of concrete is also one of the important properties of concrete. Concrete specimens of 500 x 100 x 100 mm beam were cast with different proportions of concrete.

Formulae used:

$$F = 3PL/2bd^2 \ (N/mm^2)$$

Where,

F = Flexural strength of concrete in N/mm^2.

P = Failure load in Newton (N).

L = Effective span of the beam in mm.

B = Breadth of the beam in mm.

d = Depth of the beam in mm.

6. RESULTS AND DISCUSSION

6.1 GENERAL

In this experimental study addition of bamboo as a fibre in a concrete with differtent fibre ratio 0% - 2% .the test was conducted for 1:1.45:3.08 mix ratio and the results of tests conducted are discussed below.

6.2 COMPRESSIVE STRENGTH

The compressive strength tests were conducted on concrete cube specimens of size 150mmX150mmX150mm.The cubes were tested after curing periods of 7 days,14 days and 28 days. The compressive strength increases from 19.8N/mm2 with 0% fibre content to a maximum of 20.3N/mm2 with 1% of fibre content and then starts decreasing with an increase in fibre content..the compressive strength values obtained after 7,14 and 28 days of curing .

6.2.1 Comparison of Compressive Strength Of Specimens For 7 ,14 & 28 Days

The results of variation of compressive strength test of cubes for 7, 14 & 28 days are compared in below tables and the variation of compressive strength of all mixes are are clearly illustrated.

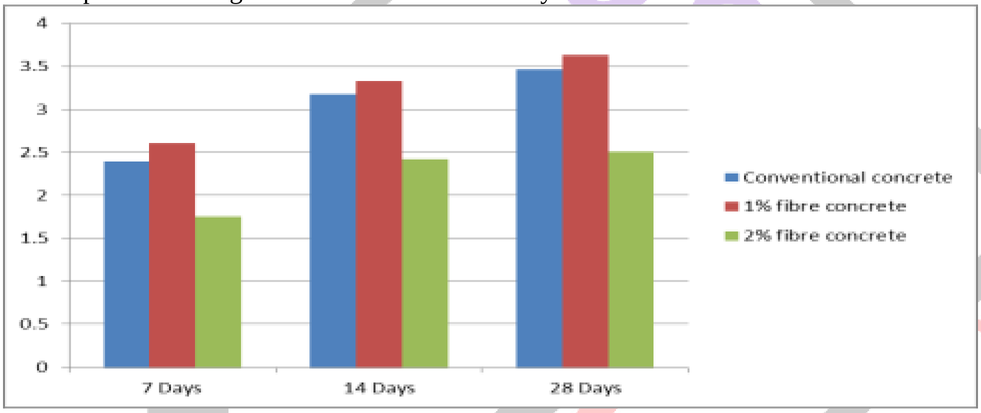

Fig 6.2.1Fibre vs compressive strength at 7 ,14 &28 days

6.3 SPLIT TENSILE TEST

Split tensile test was determined by addition of different percentage of bamboo fibre in concrete. The split tensile strength tests were conducted on concrete cylinder specimens of size 150mm dia X 300 mm height. The cylinder were tested after curing periods of 7 days , 14days and 28 days. The split tensile strength increases from 2.12N/mm2 with the 0% fibre content to a maximum of 2.35N/mm2 with 1% fibre content and then again decrease with an increase in fibre content.the split tensile strength values obtained after 7, 14 and 28 days of curing.

6.3.1 Comparison of Split Tensile Strength Of Specimens For 7 ,14 & 28 Days

The results of variation of split tensile strength test of cylinder for 7, 14 and 28 days are compared in below tables and the variation of split tensile strength of all mixes are clearly illustrated.

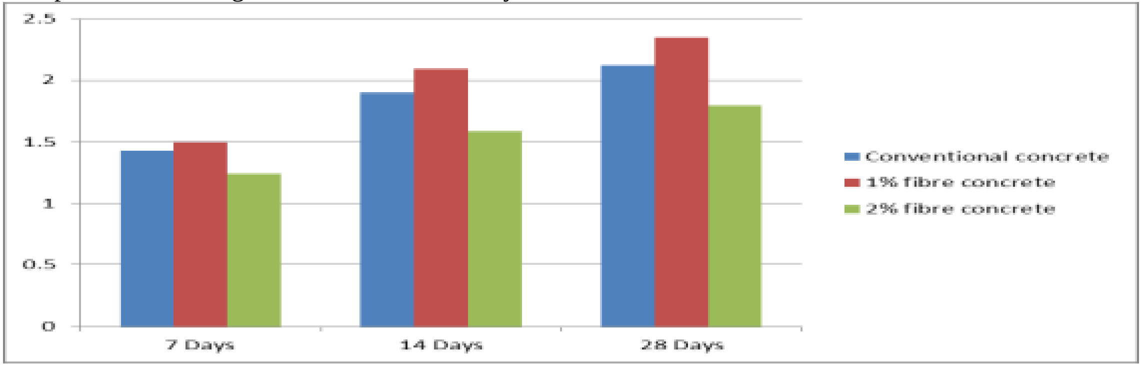

Fig 6.3.1 Fibre vs split tensile strength at 7 & 28 days

6.4 FLEXURAL STRENGTH TEST

Flexural strength test was determined by addition of different percentage of bamboo fibre in concrete. The Flexural strength tests were conducted on concrete prismatic specimens of size 100mm x 100mm x 500mm The flexural strength increased from 3.47 N/mm2 for 0% fibre content to a maximum of 3.63N/mm2 for 1.25% and then starts decreasing the flexural strength. The flexural strength for various fibre content after 7, 14, 28 days.

6.4.1 Comparison of flexural strength Of Specimens For 7 & 28 Days

The results of variation of flexural strength test of prism for 7 and 28 days are compared in below tables and the variation of flexural strength of all mixes are clearly illustrated

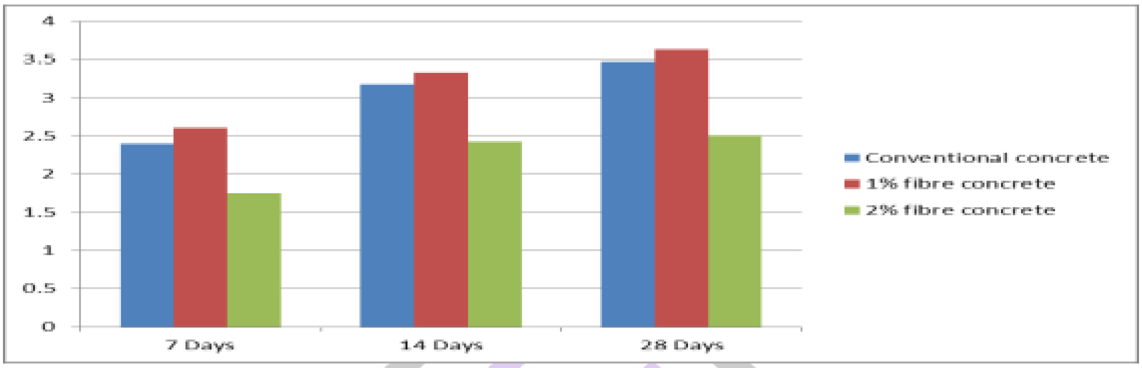

Fig 6.4.1 Fibre vs flexural strength at 7 ,14 & 28 days

7.1 CONCLUSION

Based on the experimental study on the behavior of concrete by addition of bamboo as FIBRE, the following conclusion was drawn,The cube compressive strength increases by nearly 3% to 5% for 1% addition of bamboo fibres when compared to conventional concrete specimen. It is found to decrease by 2 N/mm2 to 7 N/mm2 for 2% addition of bamboo fibres when compared to conventional concrete specimen. The flexural strength increases by nearly 4% to 9% for 1% addition of bamboo fibres when compared to conventional concrete specimen. From flexural strength test, it is found to decrease by 0.5 N/mm2 to1 N/mm2 for 2% addition of bamboo fibres when compared to conventional concrete specimen. The split tensile strength increases by nearly 5% to 10% for 1% addition of bamboo fibres when compared to conventional concrete specimen. From split tensile strength test, it is found to decrease by 0.2 N/mm2 to 0.4 N/mm2 for 2% addition of bamboo fibres when compared to conventional concrete specimen. Thus, the addition of 1% of bamboo FIBRE has shown a positive trend. It is evident that the addition of 1% bamboo fibre has increased the strength of the concrete. It is also an environmental friendly method since the availability of bamboo is in abundance and can be put to a greater use. Hence it has paved a path for an exclusive study of bamboo as fibre in the concrete technology.

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