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Performance of Bamboo Fibre and Steel Fiber Reinforced Concrete

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Abstract: Bamboo and steel are construction materials having varied engineering properties and qualities used for structural and other constructional applications. The fast growth and maturity pace of bamboo, sustainability, aesthetics, higher strength and low cost make it a strong construction material as a substitute for steel. For developing countries like India, steel is difficult to obtain because of expensive prices and for construction industry usage of steel is limited. In addition to this, production of steel has heavy consumption of fossils fuels. Hence it is very important to invent new building construction material, which is low cost, requires less sophisticated technologies and reliable construction methodology. Addition of steel fibers in discreet or patterned increases the mechanical properties of the concrete, especially flexural strength. Bamboo strips are also considered as main reinforcement by some of the researchers, while comparing the same with steel bars. Present research work deals with the addition of bamboo fibers in dispersed/ discreet form in varying content of bamboo fiber. Concrete specimens were made to check the mechanical properties of bamboo fiber concrete. In addition to this, steel fiber reinforced concrete is developed by varying content of steel fibers in concrete matrix. Comparative graph is presented with reference to mechanical properties of both the developed concrete. A notable increase in mechanical properties is observed in bamboo fiber reinforced concrete as compared to steel fiber reinforced concrete. To understand the behaviour of fiber reinforced slabs under different temperature conditions, slabs of varying thickness are casted and experimental results are collected and compared with the temperature differential recommended by IRC 58- 2015.
Keywords: Bamboo, Bamboo Reinforced Concrete, Bamboo Fibres, Steel Fibres, Sustainable recourses, Slab temperature variation, temperature differential, IRC 58-2015.

I. INTRODUCTION

Nowadays, the increasing price and common reduction of reinforcement steel in maximum divisions of the world has led to increase in the probabilistic use of conventional locally possible materials for the reinforcement. Attention of researchers and industries has turned to materials such as vegetable fibre including bamboo, soil, wastes from industry, mining and agriculture for engineering applications. Because of steel's high cost it is essential to replace with another economic and easily available material and Bamboo is acceptable and money saving substitute of steel.

In most countries, concrete is widely used as the foundation for the infrastructure. Concrete is used largely because it is economical, readily available and has suitable building properties such as its ability to support large compressive loads. However, the use of concrete is limited because it has low tensile strength. For this reason, it is reinforced, and one of the more popular reinforcing bars (rebar) is steel. Steel has a relatively high tensile strength, as high as 115 ksi (792 N/mm^2), complementing the low tensile strength of concrete. It is available and affordable in most developed countries but unfortunately not all parts of the world. In many countries, none or very little steel reinforcement is used in construction, which is evident from the crumbling of buildings. Steel reinforcement at some point may no longer be available. Even today there exists a need for more economical and readily available substitute reinforcements for concrete. In some parts of the world many buildings are constructed only with concrete or mud-bricks. This is dangerous in case of seismic activity. These buildings have little hope of standing in the case of an earthquake. Steel reinforcement would be an ideal solution, but cost is a considerable problem. Scientists and engineers are constantly seeking for new materials for structural systems; the idea of using bamboo as possible reinforcement has gained popularity. Bamboos are giant grasses belonging to the family of the Bambusoideae. It is estimated that 60–90 genre of bamboo exist, encompass approximately 1100–1500 species and there are also about 600different botanical species of bamboo in the world. Bamboo mainly grows in tropical and sub-tropical regions of Asia, Latin America and Africa. Forests and rural areas of Northeastern and Eastern India comprising the political territories of the States of West Bengal, Sikkim, Arunachal, Mizoram, and Tripura have over 50% of the bamboo species of the Indian floristic region. The energy necessary to produce 1 m^3 per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete, has been compared with that of bamboo. Bamboo is versatile resource characterized by high strength to weight ratio and ease in working with simple tools. Bamboo is the fastest growing, renewable natural resource known to us. It is a small wonder, therefore, that this material was used for building extensively by our ancestors. It has a long and well established tradition as a building material throughout the tropical and sub-tropical regions. It is used in many forms of construction, particularly, for housing in rural areas. But, enough attention had not been paid towards research and development in bamboo as had been in the case with other materials of construction including timber. Due to ecological materials and having many advantageous characteristics of bamboo, in the last few years, studies have been made on bamboo as structural material and reinforcement in concrete. Bamboo has great economic potential, especially in the developing countries, because it can be replenished within a very short time. A critical assessment of the present status and future prospects of bamboo housing would be helpful in exploiting that potential

A. BAMBOO FIBER REINFORCED CONCRETE

Bamboo is a multipurpose reserve categorized by large ratio of strength to weight and its ease of work with simple tools. It is one of the rapidly growing natural reserves also it is easily and locally available. Bamboo had been using for construction even from early times. It can be used as Technical and Non-Technical ways. For building the houses our forefathers used Bamboo as basic material. Because of its high strength to weight ratio, traditionally it has been used in varied living facility and tools. This property is due to the longitudinal alignment of fibers. Bamboo fibers have better modulus of elasticity than any other natural material. The longer is the fiber the higher it gives the tensile strength. Addition of Bamboo fibers to the concrete elevates the mechanical strength. It has low specific weight too. As the bamboo fibers are susceptible to the biological attacks; that is from fungus, termites etc… It was given treatment of Wood Guard’s anti-termite solution. In practice, in addition to the extraction of bamboo fibers in controlled way from bamboo trees it is mandatory to fabricate the bamboo based composites.

II. METHODOLOGY

To effectively study the improvement in the mechanical properties of the bamboo fiber reinforced concrete, planning, procedures and methods must be wisely chosen. The criteria to assess mechanical properties are based on the activities to plan and preparation, which carried out before the testing of the fresh and hardened properties of bamboo fiber reinforced concrete. These activities are:

- Preparation of bamboo fibers
- Aggregates testing
- Bamboo fiber dosage rate
- Mix design
- Preparation of test specimens
- Concrete mixing

From literature Bamboo fibre is chosen for making the concrete mix with different proportions of Bamboo fibre for obtaining the strength variation at 0.5%,1%,1.5% & 2% and for making the Bamboo fibre reinforce concrete.Different materials which are described below:

i) Selection of Bamboo Species: Bamboo showing a pronounced brown colour must be chosen. This will insure that the plant is at least three years old, Select the longest large diameter culms available, Do not use whole culms of green, unseasoned bamboo, Avoid bamboo cut in spring or early summer, These culms are generally weaker due to increased fibre moisture content.

ii) Seasoning : As the bamboo is often attacked by fungus and termites, hence it should be treated chemically according to IS 401 (2001) with Copper-Chrome-Boron (CCB) solution confirming to IS 9096 (2006). Its durability varies with the type of species, age, conservation condition, treatment, and curing. Curing should be initiated when bamboo is being cut in the bamboo grove. When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using.The chemicals used for seasoning are Borex, Copper sulphate, Boric Acid

Fig 1: Boric acid

Fig2: Copper Sulphate

iii) Sizing: Splitting the bamboo has been done by separating the base with a sharp knife and then pulling a dulled blade through the stem. The dull blade will force the stem to split. Then it can be cut easily in required size for bamboo fibre.

iv)Waterproof Coatings: When seasoned bamboo, either split or whole is used as reinforcement; it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged, especially if more than 4 percent bamboo is used. Hence, Bitumen as a coating material has been used on Bamboo fibre for making it waterproof. Addition to bitumen a uniform coating of silica sand is also applied which provides proper bonding.

Fig:3 Bitumen Coating of Bamboo Fibre

A. MATERIALS

i) CEMENT:

The cement used was Pozzolana Portland cement (PPC) with a specific gravity of 3.11 Initial and final setting times of the cement were 69 min and 195 min, respectively. Its chemical composition is given m Table. No 1

Table1: Chemical composition of cement.

Chemical components	Content (%)
SiO2	19.71
Al2O3	5.20
Fe2O3	3.73
CaO	62.99
MgO	2.54
SO3	2.72
K2O	0.90
Na2O3	0,25
LOI	0.96

ii) AGGREGATE :

a) Fine Aggregate (Crushed Sand): Good quality crushed Sand has been used as a fine aggregate.

b) Coarse aggregates: The material whose particles are of size as are retained on I.S Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 20mm size crushed angular in shape. The aggregates are free from dust before used in the concrete.

iii) FIBRES :

Fiber or fibre is a natural or syntheticsubstance that is significantly longer than it is wide. Fibers are often used in the manufacture of other materials. The strongest engineering materials often incorporate fibers, for example carbon fiber and ultra-high-molecular-weight polyethylene.

Synthetic fibers can often be produced very cheaply and in large amounts compared to natural fibers, but for clothing natural fibers can give some benefits, such as comfort, over their synthetic counterparts.Natural fibers develop or occur in the fiber shape, and include those produced by plants, animals, and geological processes,Human-made or chemical fibers are fibers whose chemical composition, structure, and properties are significantly modified during the manufacturing process. Man-made fibers consist of regenerated fibers and synthetic fibers.

B. TYPES OF FIBRE:

Fibres vary in types, geometry, properties and availability in construction industry. Most common types of fibres are steel fibres, glass fibres, and polypropylene fibres. These usages may alter in concrete for different applications. The fibres are selected from their properties like, effectiveness, cost and availability. Special types of fibres such as carbon, and Kevlar, natural fibres, mineral fibres, and asbestos fibres may use in harsh environment. These differences and usage of fibres depends on the requirement of behavior and properties for a concrete, allowing the increase the explicit effects and mechanical properties. Fibre geometry varies from hooked end fibres, deformed fibres, deformed wires, fibre mesh, wave-cut fibres, large end fibres till different types and geometries.

Fibre used in this research work for preparation of concrete specimens are mainlySteel fibres and Bamboo fibre

1. Steel Fibre:

Steel fibre is one of the most commonly used fibre. Generally, round fibres are used. The diameter may vary from 0.25 to 0.75 mm.Flat steel fibre having length 60 mm have been adopted. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of the fibres takes place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete. It has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks.

Figure4: Steel Fibre

2. Bamboo Fibre:

Bamboo fibers are often known as natural glass fiber due to its high strength with respect to its weight derives from fibers longitudinally aligned in its body . The tensile strength of bamboo is relatively high and can reach 370 MPa . This makes bamboo an attractive alternative to steel in tensile loading application Bidirectional bamboo fiber has been used as a reinforcing material in all composite. These are collected from local sources. Bamboo belongs to grass family Bambusoideae. It is a natural Lignocellulosic composite, in which cellulose fibers are embedded in the lignin matrix.

Bamboo fiber reinforced have been fabricated with varying fiber concentration. The experimental analysis has shown that bamboo fiber reinforcement in the epoxy matrix has improved the mechanical properties of composite structure. The composites have been fabricated using the hand-lay-up method, which is one of the simplest methods to fabricate the composites under normal conditions. The fabricated composites are of good quality with appropriate bonding between the fiber and resin.

Figure 5: Bamboo Fibres/strips without coating

C. TEST ON MATERIALS:

The ingredients of bamboo fiber reinforced concrete are cement, fibre, aggregate and water. For the mix design calculations the data of materials like specific gravity, setting time of cement, etc. for which different test have been conducted on materials which is describe below:

1. Test on Cement 2. Test on Aggregates 3. Test on bamboo

i) Test on Cement

1. Fineness Test:

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength. The fineness of grinding has increased over the years. But now it has got nearly stabilized. Different cements are ground to different fineness. Fineness of cement is tested by sieving.

2. By Sieving:

Weigh correctly 100 grams of cement and take it on a standard IS Sieve No. 9 (90 microns). Break down the air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes. Mechanical sieving devices may also be used. Weigh the residue left on the sieve. This weight shall not exceed l0 for ordinary cement. Sieve test is rarely used.

Table2: Fineness of Cement

Sr. No.	Weight of Sample taken (gm)	Weight of Sample Retained on Sieve	% Weight Retained
1	100	7	7%
2	100	8	8%
3	100	6	6%

Average retained weight = (7+8+6)/3 = 7 %

After the experiment work, the fineness of the cement is obtained by sieve method. The average fineness of the cement is 93 % which means it passed the standard because it is clearly not less than 90%. Other sources of errors could come from carelessness while sieving and wrong calculations.

3. Standard Consistency Test:-

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould. The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC).

Table 3: Standard Consistency Test

Sr.No.	Water added for different Trials in percentage	Penetration of plunger from bottom in mm
1	25%	33
2	28%	15
3	32%	7

$$\text{Standard consistency in percentage} = \text{Total water for standard consistency} \times \frac{100}{400}$$
$$= 128 \times \frac{100}{400}$$
$$= 32\ \%$$

This experiment specifies the amount of water content at which the maximum strength of cement can be obtained.The achieved Standard Consistency is coming within the range of water(26% to 33%) So, the standard consistency of cement paste is 32%.Moreover the temperature and humidity values were not in the specified range.

4. Setting Time Test:

The initial setting time is the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting. placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement products remain in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. Once the concrete is placed in the final position, compacted and fished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is often referred to as final setting time.

D. TEST ON AGGREGATES:

1. Sieve Analysis test

This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 mm etc. Under such a system, employing a logarithmic scale, lines can be spaced at equal intervals to represent the successive sizes. The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm are termed as coarse aggregate and those fraction from 4.75 mm to 150 micron are termed as fine aggregate. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate (C.A. and F.A.)

2. Specific Gravity Test:

In concrete technology, specific gravity of aggregates is made use of in the specific gravity of each constituent design calculations of concrete mixes with the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Specific gravity of aggregate is also required in calculating the compacting factor in connection with the workability measurements. Similarly, specific gravity of aggregate is required to be considered when we deal with light weight and heavy weight concrete.Results of the test on coarse aggregate and fine aggregate is presented in table 4 and table 5.

Table 3: Specific Gravity of Coarse Aggregate

Sample	1	2	3
Empty wt of pycnometer (W1) in gm	606	606	606
Weight of pycnometer Oven-dry soil (gm) (W2)	1096	1068	1132
Weight ofpycnometer+water+soil(gm) (W3)	1832	1816	1856
Weight of pyncnometer_water(gm) (W4)	1508	1508	1508
Sp. Gr. of fine aggregate	2.95	3.00	2,97
Average	**2.967**		

The Specific gravity of Coarse aggregate is 2.967.The specific gravity of coarse aggregate is between 2.4 to 2.9 hence it suitable for construction work.

Table 4: Specific Gravity of Fine Aggregate

Sample	1	2	3
Empty wt of pycnometer (W1) in gm	1152	1124	1032
Weight of pycnometer Oven-dry soil (gm) (W2)			
Weight of Oven dry silt =W2-W1	1868	1841	1788
Weight ofpycnometer+water+soil(gm) (W3)	1508	1508	1508
Weight of pyncnometer_Water(gm) (W4)			
Sp. Gr. Of fine aggregate	2.93	2.8	2,91
Average	**2.88**		

The Specific gravity of Crushed Sand is 2.88.The specific gravity of fine aggregate is between 2.6 to 3.0 hence it suitable for construction work

D. TEST ON BAMBOO

1. Tensile strength test on bamboo:

In order to conduct the tensile tests, it was necessary to prepare the bamboo samples. First, the samples were cut to the proper size and shape. The length of the samples was largely determined by the distance between the nodes. The widths of the samples were reduced since some of the original samples were too strong to be broken.The thickness, along with the width, differed between the samples because Bamboo is a natural material whose physical properties vary. For this reason a careful dimensioning of the sample was done before testing the bamboo.The dimensions were measured at three points along the length of the sample. To calculate average dimensions of the test specimen. The three points included the midpoint, two end points approximately halfway between the middle and the ends. The distance between these points was measured and recorded, along with the width and thickness.

Figure 7: Bamboo strips

The tensile strength of bamboo strip was tested using Universal Testing Machine (UTM) Specimen was placed in UTM and tensile load was being applied until rupture. Elongation was measured at regular interval of applied tensile load. The load was recorded at regular interval of elongation for a sample and also load at which a bamboo strips failed was recorded. During these tensile tests, it is observed that specimens were failed at node and at end point.

Details of sample specimen are as follows

- Avg length =750 mm
- Avg width = 30.9 mm
- Avg depth = 19.3 mm
- Rupcture Load = 29.40 kN

Equation 1.1 : Tensile Strength

$$\text{Tensile Strength} = \frac{\text{Load}}{\text{Area}} = \frac{29.40 \times 10^3}{30.9 \times 19.3} = 49.29\ \text{N/mm}^2$$

Figure 8: Tensile test on Bamboo

2. Compressive strength

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension(being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.Compressive strength is often measured on a universal testing machine

Figure 1: Bambusa bamboo Specimen

Details of sample sample specimen
- Avg Inner Diameter = 49 mm
- Avg Outer Diameter = 82.5 mm
- Avg thickness = 22 mm
- Area =4181.26

Equation 1.2 : Compressive Strength

$$\mathrm{CompresiveStrength} = \frac{\mathrm{Load}}{\mathrm{Area}}$$

$$\mathrm{Area} = \frac{\pi}{4}[\mathrm{D}^2 - (\mathrm{D} - 2\mathrm{N})^2]$$

$$= \frac{\pi}{4}[(82.5^2) - (49^2)] = 881.41 \text{ mm}^2$$

$$\text{CompressiveStrength} = \frac{114.50 \times 10^3}{881.01} = 130.01 \text{ N/mm}^2$$

Figure 10: Compressive test on Bamboo

E MIX DESIGN:

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. plastic concrete is not workable.it can not be properly placed and compacted. property of workability, therefore, becomes of vital importance.The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipments.

1. Requirements of concrete mix design:

The requirements which form the basis of selection and proportioning of mix ingredients are:

a) The minimum compressive strength required from structural consideration .

b)The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio or maximum cement content to give adequate durability for the particular site conditions.

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete

2. Ambuja Concrete Mix Design

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix = Cement:Sand:Aggregates. The ambuja concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which requires higher grades of concrete such as M25 and above and large construction projects where quantity of concrete consumption is huge..

Benefits of ambuja concrete mix design is that it provides the right proportions of materials, thus making the concrete construction economical in achieving required strength of structural members. As, the quantity of concrete required for large constructions are huge, economy in quantity of materials such as cement makes the project construction economical.

Concrete mix design

Mix design for M30

- Grade designation = M30
- Type of cement = Pozzolana Portland Cement 53 Grade
- Max nominal size of aggregate = 20 mm
- Minimum cement Content = 240 kg/m3
- Water-Cement Ratio = 0.45

- Standard deviation = 5 N/mm2
- Crushed Sand conferming to Zone 1
- Exposure Condition = Moderate
- Workability = Low (25 mm -75 mm)
- Target mean Strength = 38 N/mm2

After various calculations and corrections of oversize,specific gravity the final quantity of materials are calculated

- Cement = 395.26 kg
- Water content = 177.876 kg/cum
- Fine Aggreagate = 1059.06 kg
- Coarse aggregate = 20 mm = 662.21 kg/c

= 10 mm = 19.45 kg/cum

By using this quantity of material a mix design of concrete is prepared .This mix design helps in achieving a desire workability,strength and durability for concrete work.For making the mix design more workable admixture is also used.

F. CALCULATION OF MECHANICAL PROPERTIES:

1. Compressive strength test

Compressive strength of a concrete is a measure of its ability to resist load, which tends to crush it. Most common strength test on hardened concrete is compressive test. It is because the test is easy to perform. Furthermore, many desirable characteristic of concrete are qualitatively related to its strength and the importance of the compressive strength of concrete in structural design. The compressive strength gives a good and clear indication that how the strength is affected with the increase of Bamboo fibre and Steel fibre volume dosage rate in the test specimens.

The compressive strength of concrete can be calculated using the following formula .

Equation 1.3 : Compressive strength of concrete

$$F_c = \frac{P}{L}$$

Fc-Compressive strength of concrete (Mpa).

P- Maximum load applied to the specimen in N.

A - Cross sectional area of the specimen (mm^2).

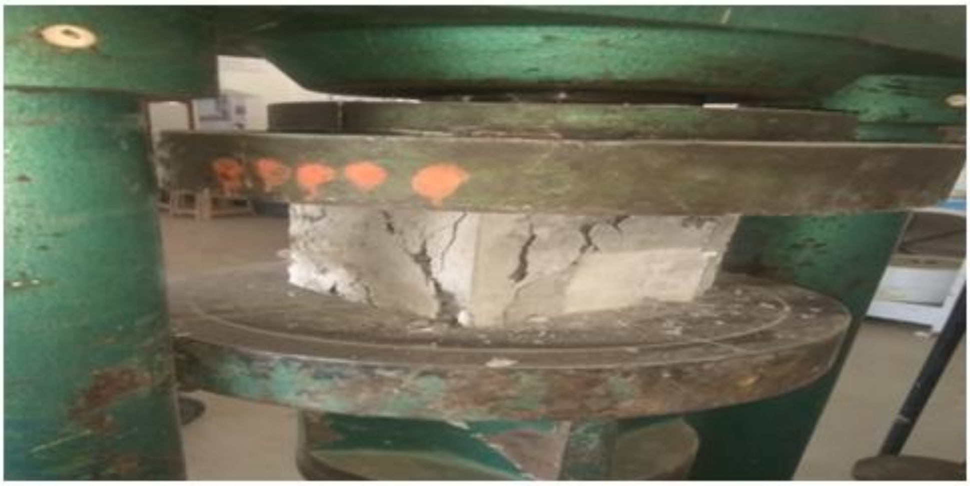

Figure 11: Compressive test

2. Splitting tensile strength test

Tensile strength of a concrete is a measure of its ability to resist forces, which stretch or bend it. Unlike steel, the concrete is sufficient in strength only in one direction. The tensile strength of concrete is approximately one-tenth of the compressive strength and it is not generally used in the design of concrete structure. Nevertheless, it is an important property in many applications. Addition of fibre is one of the primary reasons to increase the tensile strength. The task of this test was Performed to find the increase and differences of strength according the increasing Percentage of fibre in the concrete. The indirect tensile strength test was conducted in the laboratory after the concrete specimens were cured for 28 days.

The indirect tensile strength of concrete is calculated using the following formula:
Equation 1.4 ; Tensile strength of concrete

$$F_{ct} = \frac{2P}{\pi} \times L \times D$$

Where: f ct –Indirect tensile strength of concrete (Mpa).
P - Maximum load applied to the specimen in N.
L - Length of the specimen in mm.
D - Diameter of the specimen in mm

Figure 12: Splitting tensile strength test

3. Flexural strength test

Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture'. Concrete specimens for flexural strength were cross sectional area of 100mm width with 100mm depth and length of 500 mm concrete beam In this test, the load/deformation behavior is much more important than the modulus of rupture. It tells more information about the behavior and effect of each type of the short fibres applied in the concrete. The task of this test was performed to find the increase and differences of strength

According the increasing percentage of bamboo and steel fibre in the concrete,in both pre-crack and post-crack behavior, as fundamental to assess and evaluate the effects of the additional of short fibres on the behavior of concrete. The flexural strength test was conducted in the material laboratory. The concrete specimens were cured for 28 day.

The flexural strength of concrete can be calculated using the following formula:
Equation 1.5 : Flexural strength of concrete

$$F_{cf} = \frac{P \times L}{B \times D^2}$$

Where: :Fcf - Flexural strength of concrete (Mpa).
P - Maximum load applied to the specimen in N.
L - Length of the specimen in mm.
B - Width of the specimen in mm
D - Depth of the specimen in mm

Figure 13: Flexural strength test

G. STUDY OF TEMPERATURE DIFFERENTIAL IN DIFFERENT CONCRETE SLAB OF VARIYING THICKNESS

The stresses developed in rigid pavement include load stress, shrinkage /expansion stress and temperature stress. Temperature stresses develop due to the change in temperature from top to the bottom region of the concrete slab, hence the stresses in concrete also various with change in temperature differential Temperature differential is the important parameter consider for design of rigid slab. Temperature is an important environmental factor that influence the performance of concrete slab. Warping which results from the temperature gradient between the concrete slab at top and bottom surface.The behaviour of rigid slab are observed due to variation of slab thickness in Amravati region of mix proportion M30 concrete slab at different layers. The top layer of slab will have maximum temperature than middle and bottom layer during day time and which will be vice-versa at night.

The slabs of thickness 150 mm,200 mm,250 mm,300 mm,350 mm and 400 mm was prepared with M30 grade of concrete.Using Mercury Thermometers the temperature readings of different layers of slab has been taken, as the thermometer has been placed at three layers top, middle and bottom layer of slab. Temperatures are recorded for the plain M30 grade concrete. The temperature readings are recorded for top, middle & bottom layer of the normal concrete, every hour for a period of one days.

The result is obtained from present investigation conducted on normal M30 concrete slab. The maximum temperature occurred during a day and minimum temperature at night.

Figure 14: Concrete slab with Thermometer

III. RESULT AND DISCUSSION

This section of paper is focused on experimental results obtained from each test and analysis. The test result and experimental test is carried out to obtained the mechanical properties and behavior include workability, compressive strength, tensile strength, flexural strength. Effect of increasing bamboo fiber and steel fiber percentage and at the same time reducing the same quantity of cement in performance of bamboo fiber reinforced concrete (BFRC) was studied. The observation for 7,14,28 days curing were recorded and present in the form of table and graph.

1. SLUMP CONE TEST

Table 6: slump cone test for M30 grade concrete

Percentage of fiber	Slump in (MM)
0	25
0.5	24
1	22
1.5	22
2	20

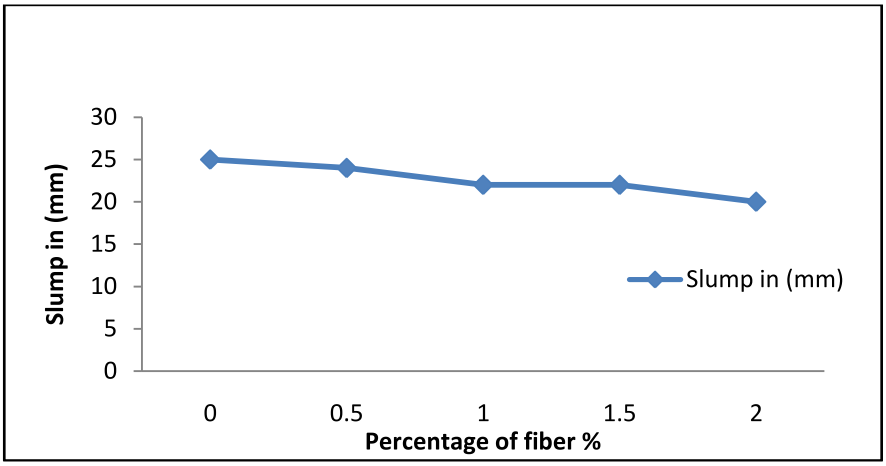

Fig 15: Slump cone test results

From the above figure 15 it has seen that the slump obtained from the concrete mix M30 is reducing as the percentage of fiber is increasing. Initially the slump value is high but then with increase in the fiber content for M30 grade of concrete a drop in slump value was observed.

2. MECHANICAL PROPERTIES OF BAMBOO AND STEEL FIBRE REINFORCED CONCRETE

I) Compressive strength:

Compressive strength of concrete is the tendency of concrete to resist load which tends to crush it. It is one of the most common test carried on hardened concrete and its easy to perform. The compressive strength gives a good and clear idea that how the strength is affected with the increase of volume dosage rate in the test specimens

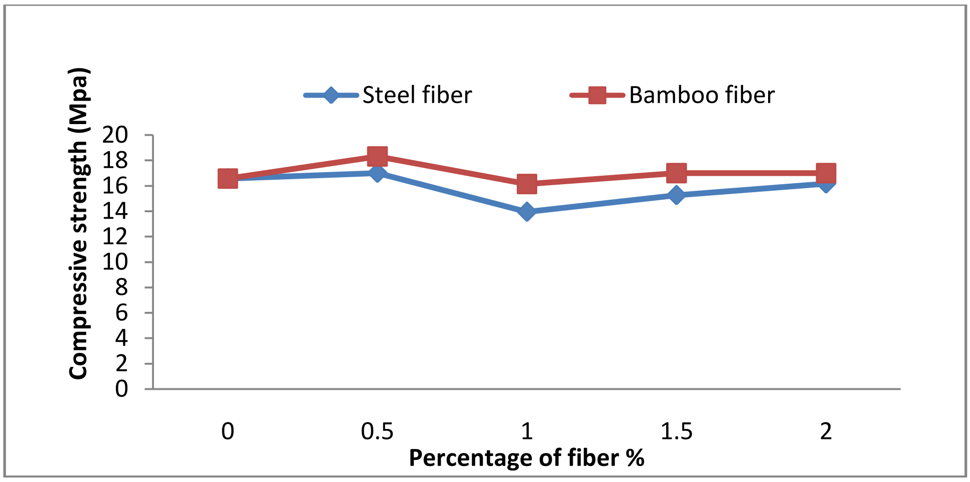

Fig16 : Compressive Strength for 7 days

From the above graph it has been seen that the compressive strength of M 30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 7 days testing and it has been increased linearly for 0.5% bamboo and steel fiber. For 1% it has decreased by nearly 2Mpa for both steel fiber and bamboo fiber ,for 1.5% we again observe rise in compressive strength nearly 2Mpa,and finally for 2% it is nearer to each other .Overall , the compressive strength for 7 days of bamboo fiber is more compared to steel fiber for all the percentage of fiber mentioned above.

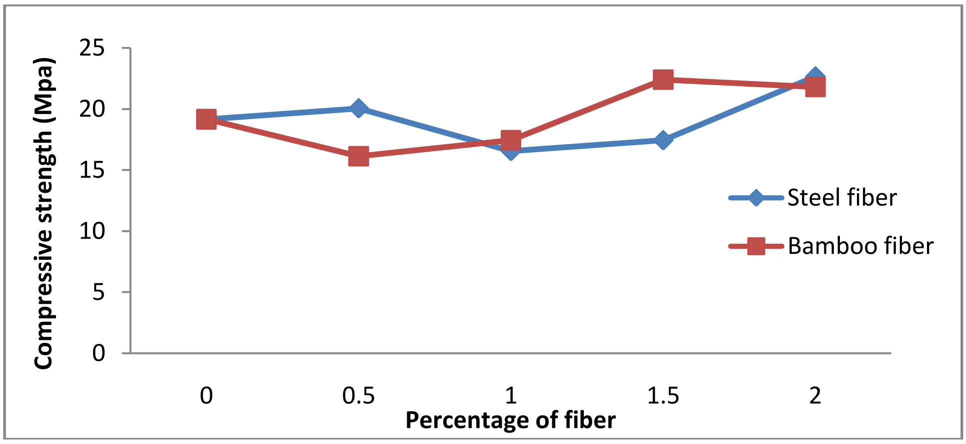

Fig. 17: Compressive strength for 14 days

From the above graph it has been seen that the compressive strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 14 days testing and it has been increased linearly for 0.5% steel fiber and decreased for bamboo fiber. For 1% it has decreased by steel fiber and a rise is seen by bamboo fiber ,for 1.5% we again observe rise in compressive strength for both bamboo fiber and steel fiber ,and finally for 2% it is nearer to each other by decrease in compressive strength by bamboo fiber and increase in steel fiber .Overall , the compressive strength for 14 days of steel fiber is more compared to bamboo fiber at the end percentage for 2 %.

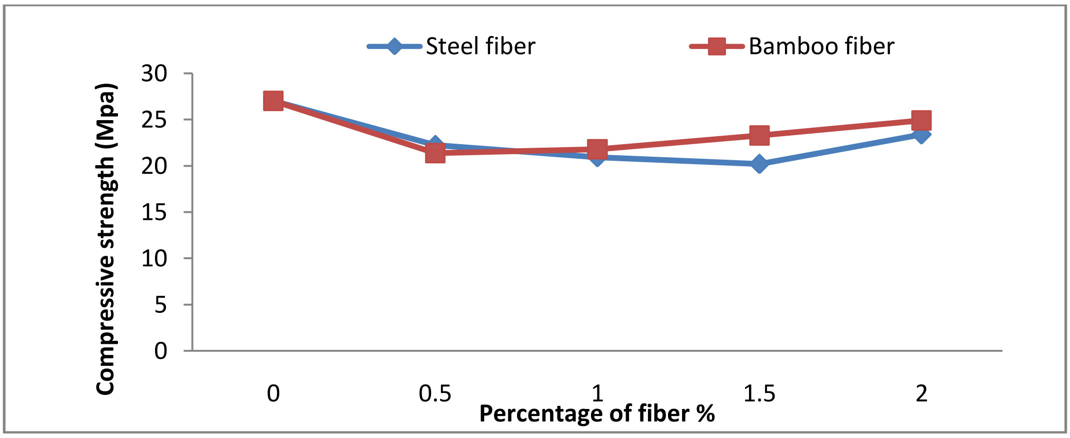

Fig 18: Compressive strength for 28 days

From the above graph it has been seen that the compressive strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 28 days testing and it has been decreased linearly for 0.5% steel fiber and bamboo fiber. For 1% it has decreased by steel fiber and a rise is seen by bamboo fiber ,for 1.5% we again observe rise in compressive strength for both bamboo fiber and steel fiber ,and finally for 2% it is nearer to each other by rise in compressive strength by bamboo fiber and increase in steel fiber.Overall , the compressive strength for 28 days of bamboo fiber is more steel to bamboo fiber at the end percentage for 2 %.

2. Split tensile strength

Tensile strength of concrete is a measure of its ability to resist forces ,which stretch of bend it. Unlike steel , the concrete is sufficient in strength only in one direction. The tensile strength of concrete is approximately one-tenth of the compressive strength and it is not generally used in the design of concrete structure. Nevertheless , it is an important property in many applications. Addition of fiber is one of the primary reasons to increase the tensile strength. The task of the test was performed to find out the increase and differences of strength according the increasing percentage of fiber in the concrete.

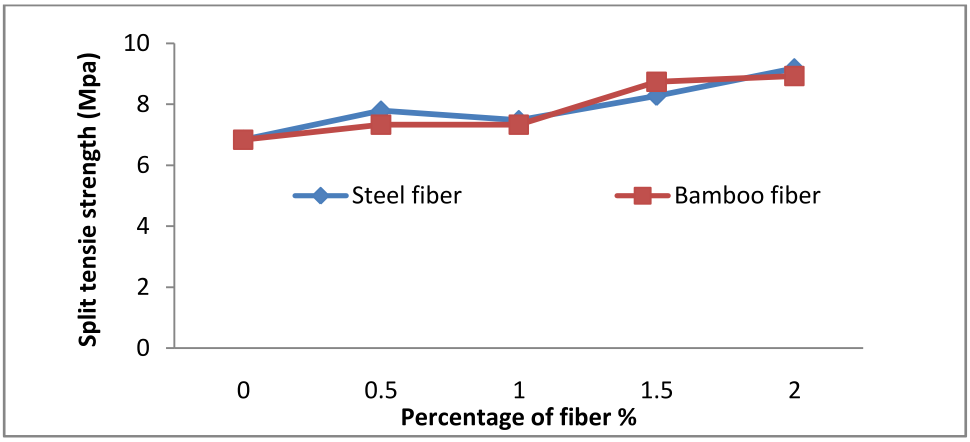

Fig. 19: Split tensie strength for 7 days

From the above graph it has been seen that the tensie strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 7 days testing and it has been increased linearly for 0.5% steel fiber and bamboo fiber. For 1% it has decreased by steel fiber and it remains constant for bamboo fiber ,for 1.5% we again observe rise in tensile strength for both bamboo fiber and steel fiber ,and finally for 2% it is nearer to each other by rise in tensile strength by bamboo fiber and steel fiber . Overall , the tensile strength for 7 days of steel fiber is more than bamboo fiber at the end percentage for 2 %.

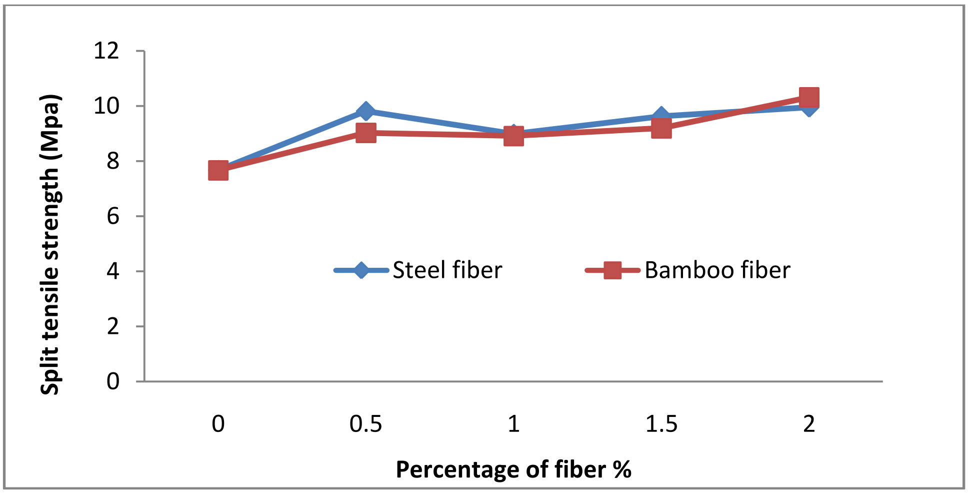

Fig. 20: Split tensile strength for 14 days

From the above graph it has been seen that the tensile strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 14 days testing and it has been increased linearly for 0.5% steel fiber and bamboo fiber. For 1% it has decreased by steel fiber and bamboo fiber and they meet at a common point ,for 1.5% we again observe rise in tensile strength for both bamboo fiber and steel fiber ,and finally for 2% it is nearer to each other by rise in tensile strength by bamboo fiber and steel fiber .Overall , the tensile strength for 14 days of bamboo fiber is more than steel fiber at the end percentage for 2 %.

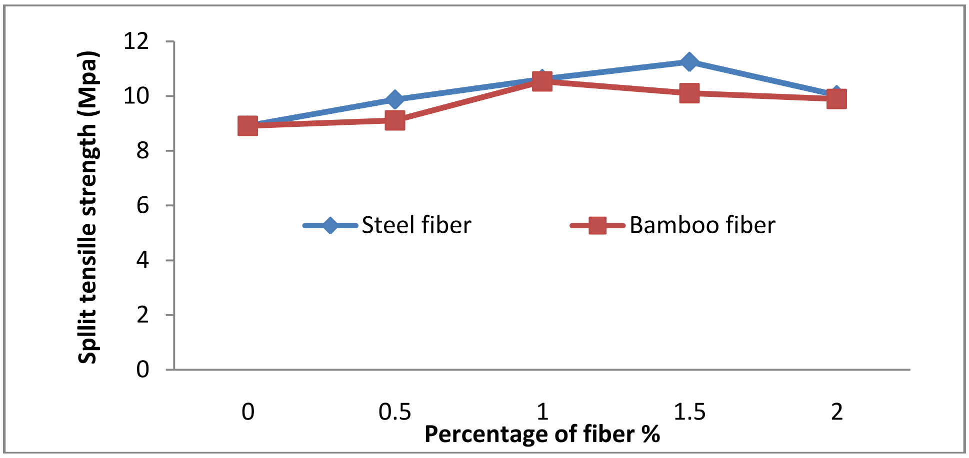

Fig. 21: Split tensile strength for 28 days

From the above graph it has been seen that the tensile strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in days testing and it has been increased linearly for 0.5% steel fiber and bamboo fiber. For 1% it has decreased by steel fiber and bamboo fiber and they meet at a common point ,for 1.5% we again observe rise in tensile strength for both bamboo fiber and steel fiber ,and finally for 2% it is nearer to each other by rise in tensile strength by bamboo fiber and steel fiber .Overall , the tensile strength for 14 days of bamboo fiber is more than steel fiber at the end percentage for 2 %.

3. Flexural strength

Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture'. Concrete specimens for flexural strength were cross sectional area of 100mm width with 100mm depth and length of 500 mm concrete beam In this test, the load/deformation behavior is much more important than the modulus of rupture.

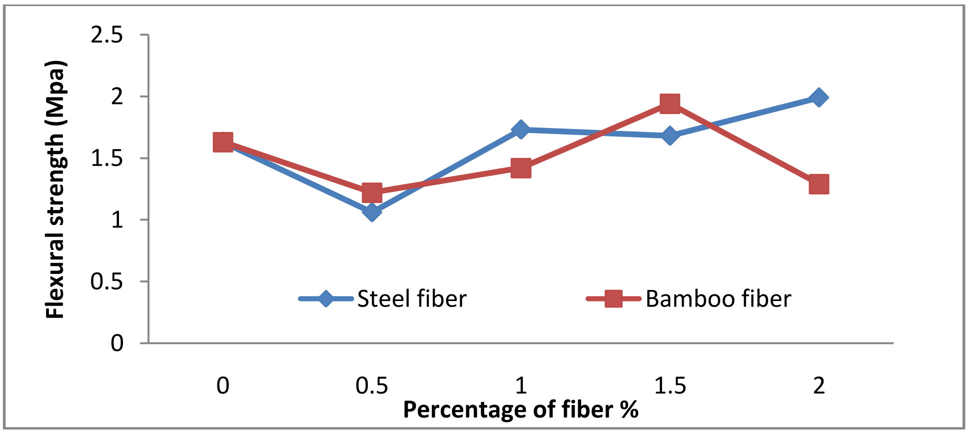

Fig 22: Flexural strength for 7 days

From the above graph it has been seen that the flexural strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 7 days testing and it has been decreased linearly for 0.5% steel fiber and bamboo fiber. For 1% it has increased by steel fiber and bamboo fiber ,for 1.5% we again observe rise in flexural strength for both bamboo fiber and steel fiber ,and finally for 2% there is steady rise in flexural strength by steel fiber and bamboo fiber .Overall , the tensile strength for 7 days of steel fiber is more than bamboo fiber at the end percentage for 2 %.Flexural strength for 14 days

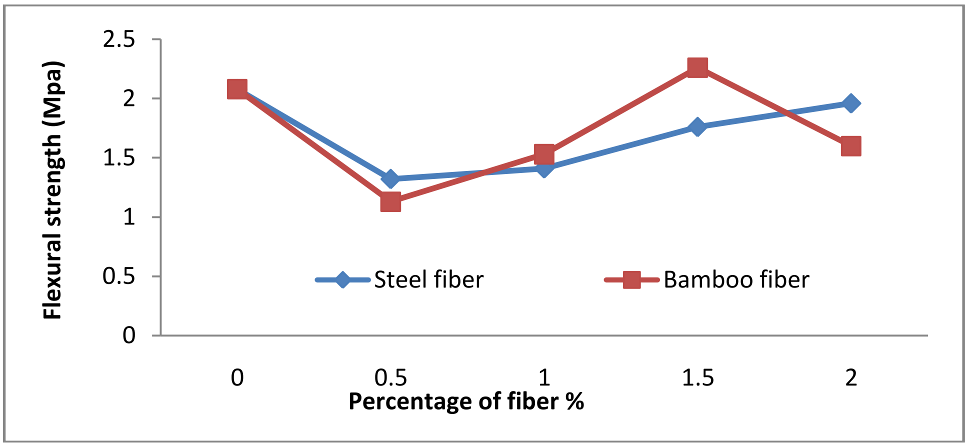

Fig 23: Flexural strength for 14 day

From the above graph it has been seen that the flexural strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 14 days testing and it has been decreased drastically for 0.5% steel fiber and bamboo fiber. For 1% it has increased by steel fiber and bamboo fiber ,for 1.5% we again observe rise in flexural strength for both bamboo fiber and steel fiber ,and finally for 2% there is steady rise in flexural strength by steel fiber and decrease for bamboo fiber .Overall , the tensile strength for 14 days of steel fiber is more than bamboo fiber at the end percentage for 2 %.

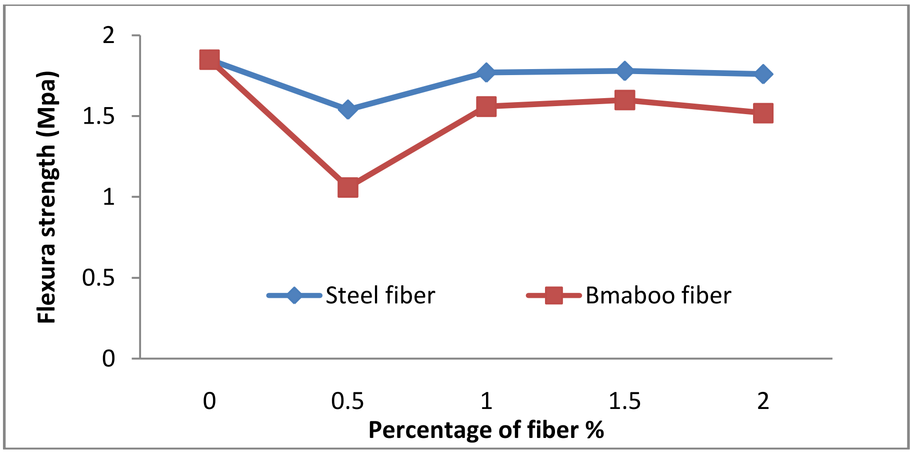

Fig 24: Flexural strength for 28 days

From the above graph it has been seen that the flexural strength of M30 grade of concrete for both steel and bamboo fiber gives satisfactory result in 28 days testing and it has been decreased drastically for 0.5% steel fiber and bamboo fiber. For 1% it has increased by steel fiber and bamboo fiber ,for 1.5% flexural strength for both bamboo fiber and steel fiber nearly remains constant,and finally for 2% there is again decrease in flexural strength by steel fiber and decrease for bamboo fiber .Overall , the tensile strength for 28 days of steel fiber is more than bamboo fiber at the end percentage for 2 %.

4. Temperature variations in concrete slab

The behaviour of rigid slab with respect to temperature are observed for 150 mm,200 mm,250 mm,300 mm,350 mm and 400 mm thick slabs in Amravati region of mix proportion M30 grade concrete slab at different layers. Using Mercury Thermometers the temperature readings of different layers of slab has been taken, as the thermometer has been placed at three layers top, middle and bottom layer of slab,the top layer of slab will have maximum temperature than middle and bottom layer during day time and which will be vice-versa at night. The following graphs shows the variation in temperature of slab with respect to time on top,middle and bottom layer.

i) For 150mm thick slab

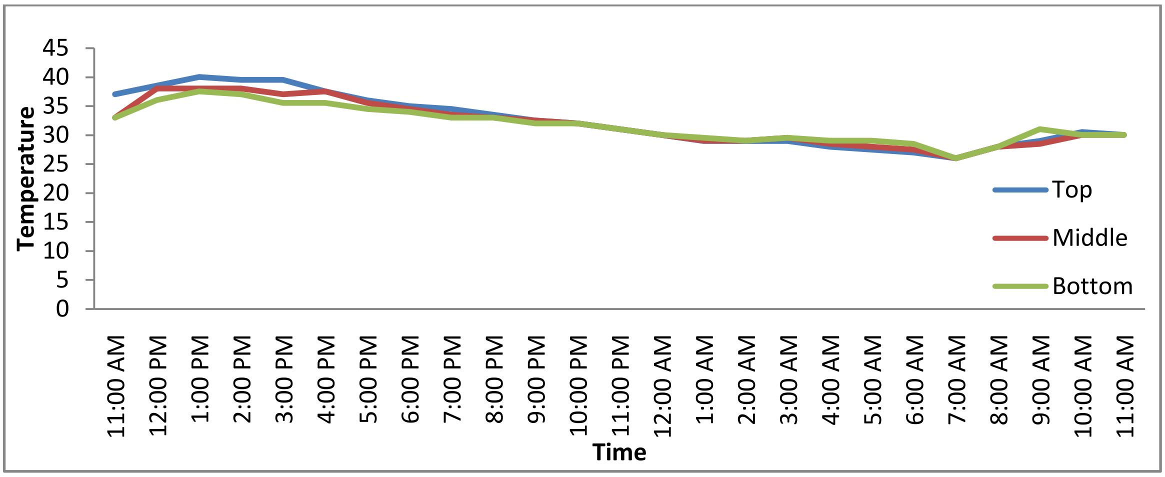

Fig 25: Temperature variations for 150mm thick slab

ii) For 200mm thick slab

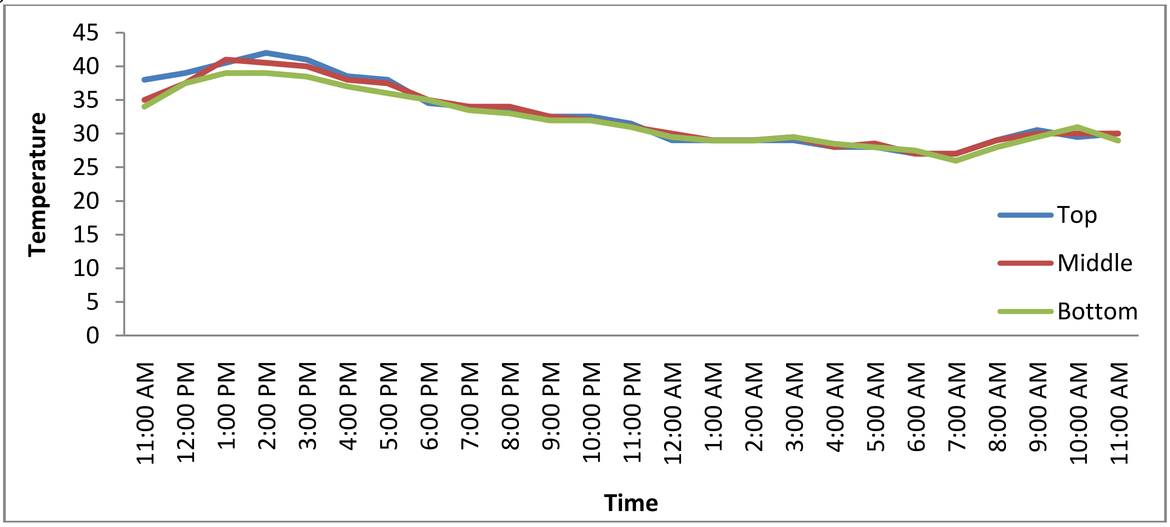

Fig26 : Temperature variations for 200mm thick slab

iii) For 250mm thick slab

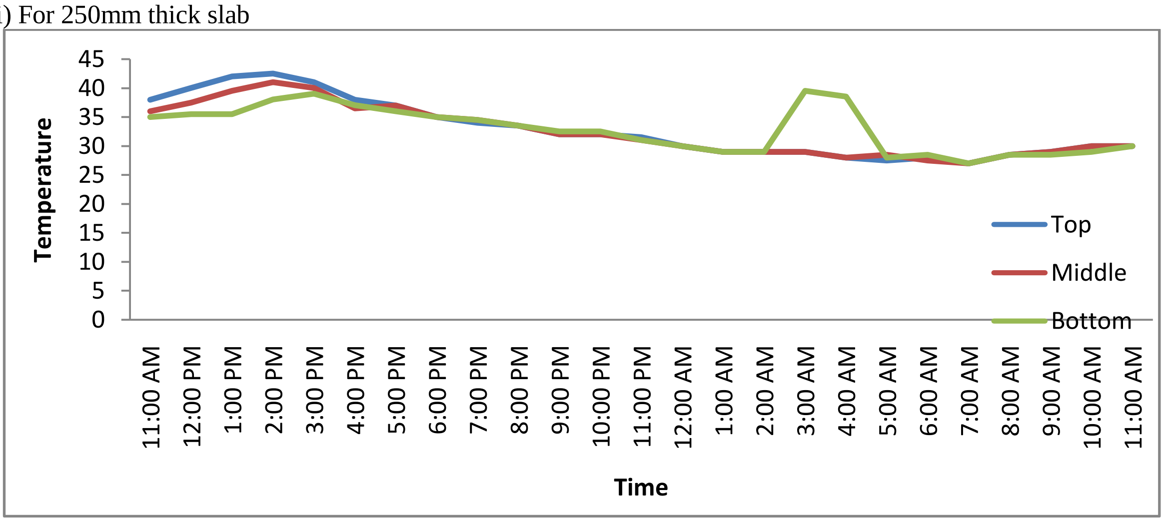

Fig 27: Temperature variations for 250mm thick slab

iv) For 300mm thick slab

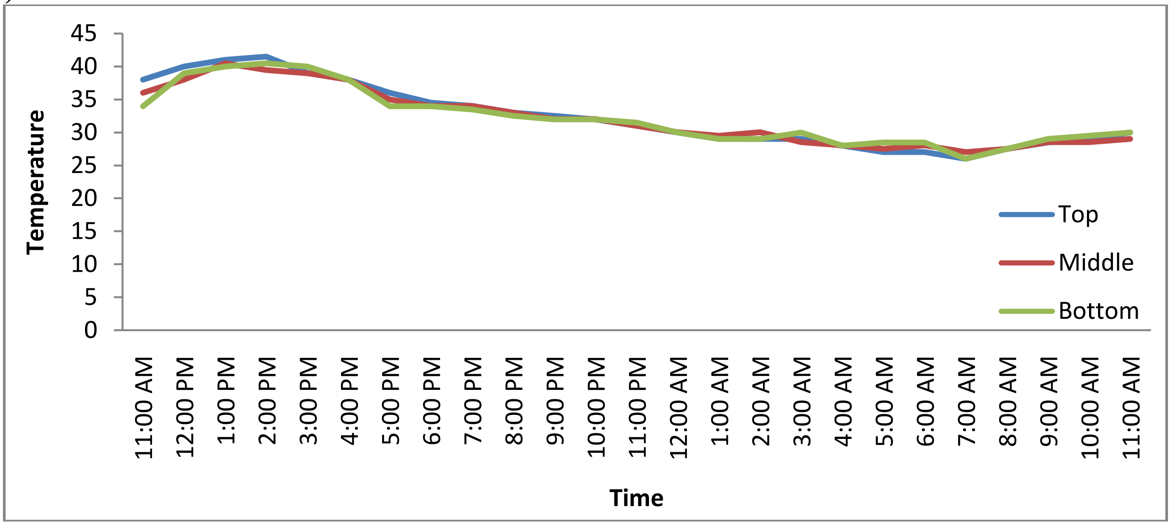

Fig 28: Temperature variations for 300mm thick slab

v) For 350mm thick slab

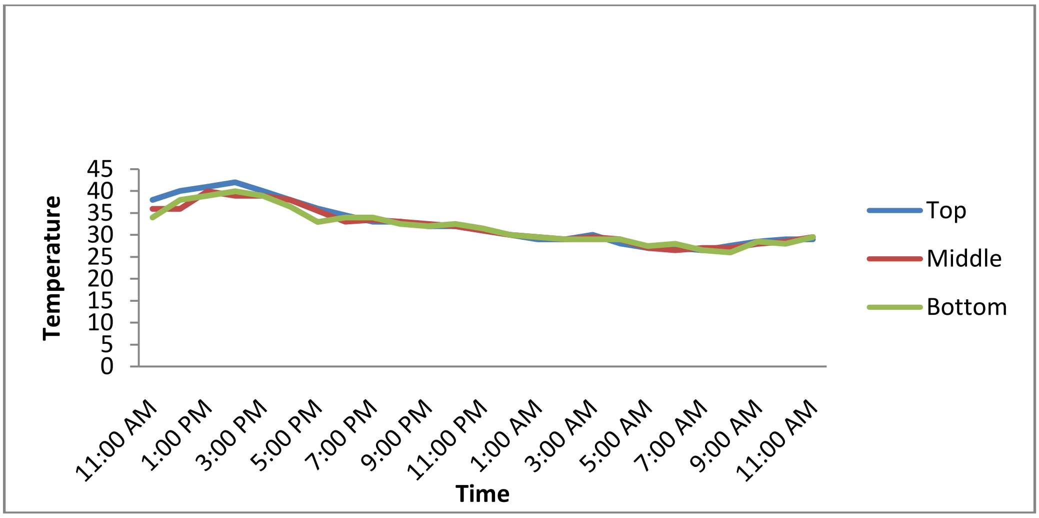

Fig 29: Temperature variations for 350mm thick slab

vi) For 400mm thick slab

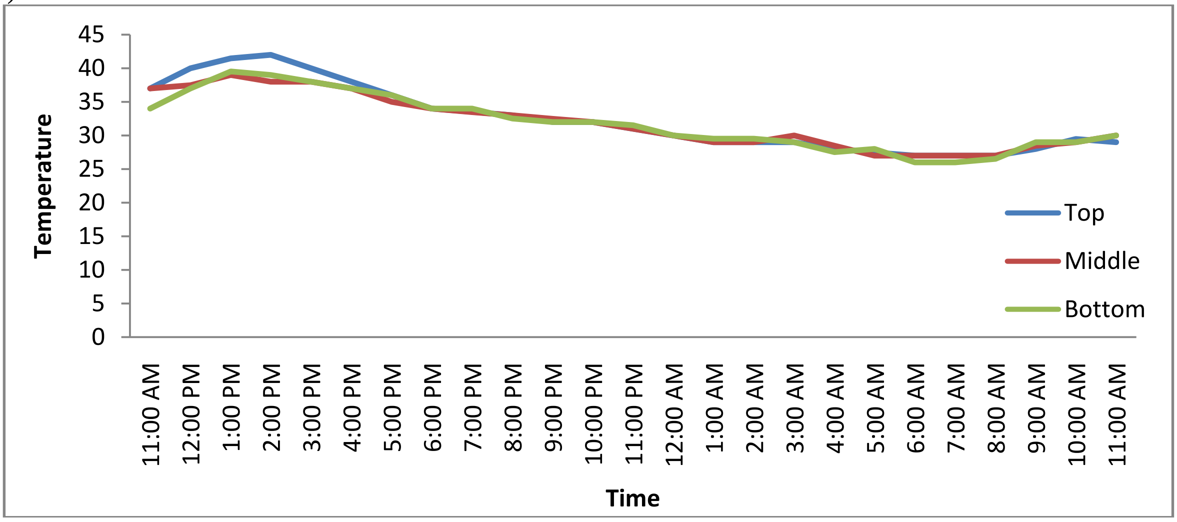

Fig 30: Temperature variations for 400mm thick slab

IV. CONCLUSION

The paper presents the research on the use of bamboo fiber for achieving the successful activation of the remarkable mechanical strength of a renewable resource in the form of a sustainable composite material, which can be successfully applied as a reinforcement system in structural concrete, does not only come along with huge environmental benefit (e.g the reduction of carbon footprints) but has an immense socioeconomic impact.The effect of different dosage of fiber may give various result for compressive strength test, splitting tensile strength test and flexure strength test. From the test following conclusionhave been drafted:

a) It can be said that this study is the first step towards the development for the future. It is important to accumulate further experimental data and to consider the practical application.
b) The investigation primarily determines the feasibility of bamboo fibre in concrete for sustainable construction development.
c) Bamboo Fiber shows good potential and increased strength when used in the Fiber reinforced concrete.
d) The fibers acts as a crack resistors, hence take up a lot more load as compared to the conventional concrete.
e) It is also observed that, the specimens made from conventional concrete breaks immediately at failure whereas the Bamboo Fiber reinforced concrete specimen remains to be intact even at failure.
f) Inclusion of fibers improves the mechanical properties of the concrete which is an innovative low cost material which can be promoted in construction field.
g) The compresive strength of cube increases with increase in dosage of bamboo fiber for whole percentage but in case of steel fiber after 0.5% it shows a continues drop in strength.
h) The split tensile strength of cylinder is increases with the increase in dosage of bamboo fibre for all percentage but in case of steel fiber after 1 % drop in strength is observed.
i) Flexure strength of beam for bamboo fiber slightly decrease after 1% replacement and in case of steel fiber it will increases continuously for all percentage.
j) From the result of this research, it was found that bamboo can be used as reinforcement in various structural members such as beam, slab, column etc. in bamboo reinforced concrete.
k) Based on the limited number of testing conducted, it was concluded that Bamboo can potentially be used as substitute steel reinforcement. However, for regions of the world that availability of steel is limited and plain concrete members are commonly being used, the use of reinforced bamboo concrete is highly recommended.
l) It was also seen that epoxy reduces the water absorption of bamboo up to great extent.
m) The true innovation presented in this paper is not the creation and application of a new material that can serve as an alternative to steel in terms of mechanical properties but Most importantly also as an alternative in view of global socio-economic aspects.
n) In case of temperature variation in slab temperature varies according to the depth of slab with respect to the surrounding temperature. It is observed that the temperature of slab at the top layer is higher than the middle and bottom layer at the day time and vice versa at the night time.

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