International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

BAMBOO REINFORCED CONCRETE: EXPERIMENTAL INVESTIGATION ON MANGA & DAGDI BAMBOO

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Abstract - *Bamboo which is fast growing and ecologically friendly material for structural applications and is being considered as quite appropriate. The tensile strength of bamboo is high and can reach up to 125 to 150 mpa. This makes bamboo an pretty alternative to steel in reinforcement loading applications. The bamboo reinforced concrete composite elements can be used as alternate for concrete, steel and wood used in housing and other products required in the day to day applications. In this study it has been attempted to develop engineered bamboo structural elements for use in low cost housing or G+1 structures. All the experiment were carried on Universal testing machine with capacity of 1000 KN. Tensile strength test of Manga and Dagdi bamboo specimens, compressive strength test on concrete cubes of (150x150x150mm), and flexural strength test on bamboo reinforced beams of (150x150x700mm) were casted and compared with the steel reinforced conventional beam. The results displayed significant nonlinearity, representing that the bamboo has the capacity to absorb energy to some extent. Bamboo concrete composite structural members can provide tailored solutions to the eco-housing initiatives at cheaper costs. The results obtained accrue the advantage obtained by the composite members when compared that to conventional reinforced concrete.*

Key Words: Experimental Investigation, Bamboo Reinforced Concrete, UTM, Tensile Strength, Compression Strength, Flexural Strength.

1. INTRODUCTION

Problems encountered with the commonly used construction material like steel are rise in cost; degradation of the non-renewable material, the pollution of the environment due to industrial process etc. are common in the globe. However, with sustainability as a key issue in the last decades the environmental load of building materials has also become a more important criterion. The building industry, directly or indirectly causing a considerable part of the annual environmental damage, can take up the responsibility to contribute to sustainable development by finding more environmentally benign ways of construction and building. One of the directions for solutions is to look for new material applications: recycling and reuse, sustainable production of products, or use of renewable resources. Attention has to be given to materials such as vegetable fibres including bamboo, jute, and glass, wastes from industry, mining and agricultural products for engineering applications to control environmental degradation and to minimize cost [1].

1.1 - Bamboo Classification

A) Dendrocalamus Stocksii
Common name: Chivari, Mes, Manga Bamboo(Maharashtra)
Dimensions:

- Culm length: 9 m
- Culm diameter: 2.5-4 cm
- Internode length: 15-30 cm

Wall thickness: Solid culms except at the tops internodes
Distribution: Coastal areas of Maharashtra, Goa, Karnataka and Northern Kerala (Kasargode). Recommended for cultivation in the following site conditions:
Altitude: Grows well in plains and in hilly tracts up to 1200m.
Soil type: Lateritic soils.
Climatic condition: It prefers a tropical humid climate.
Planting material: Vegetatively propagated planting stock will be available and one year old planting stock should be preferred and procured from NBM recognized nurseries or NBM high tech nurseries for out planting.
Availability: Vegetatively propagated plants KFRI, Peechi; IWST, Bangalore, Uravu, Wyanad, Kerala
Tissue culture Plants: IWST, Bangalore; Grow more Biotech, Hosur, KFRI, Peechi.
Uses: Furniture, Handicrafts, construction, edible shoots.

Fig -1: Dendrocalamus Stocksii

B) Bambusa Balcooa
Common name: Dagdi Bamboo (Maharashtra)
Dimensions:

- Culm length : Upto 30m
- Culm diameter : 8-15cm Hollow
- Internode length : 20-40cm

Distribution: Indigenous to North eastern India but naturalized in many states of India.
Recommended for cultivation in the following site conditions:
Altitude- Sea level up to 600m
Soil type- Grows in a wide range of soil types but maximum productivity is seen when grown in heavy textured soil with good drainage.
Climatic conditions- Growth is profuse in tropical and tropical to sub tropical conditions
Planting material: This species does not set seed although flowering is occasionally seen, Vegetative propagation techniques are however quite successful and can be easily produced in a span of one year. Planting material produced in NBM High Tech Nurseries or accredited Tissue culture labs is recommended. This species is one of the most commonly available tissue cultured planting material in India.
Uses: Scaffolding, construction, ladders, Agarbatti sticks, edible shoots, paper.

Fig -2: Bambusa Balcooa

Due to the above advantageous characteristics of bamboo, in the last few years, studies have been made on bamboo as structural material and reinforcement in concrete.

1.2 - Objective of the study

This paper aims to determine the practicability of bamboo reinforcement for concrete beams. Whereas the mechanical properties and behaviour of steel reinforced concrete have been thoroughly studied and well documented. Therefore, the aim of this study is to provide a preliminary contribution toward the collection of the mechanical properties and behaviour of bamboo reinforced beams with respect to specific bamboo species accordingly to the availability.

2. LITERATURE REVIEW

In this research paper titled "**Experimental investigation on behavior of bamboo reinforced concrete member**", Arpit Sethia and Vijay Baradiya their work provides bamboo as a potential reinforcement in concrete. From stress-strain curves of bamboo, it can be seen that bamboo possesses low modulus of elasticity compared to steel. So, it cannot prevent cracking of concrete under ultimate load. But from the flexural test of bamboo reinforced beam, it has been seen that using bamboo as reinforcement in concrete can increase the load carrying capacity of beam having the same dimensions. For bamboo reinforced concrete beam, the load carrying capacity increased about 3 times that of plain concrete beam having same dimensions. The maximum deflection of bamboo reinforced concrete beam is about 1.5 that of plain concrete. This thesis concludes that it is possible to use bamboo as reinforcing for masonry structure. Though the tensile strength is about 1/3rd that of steel, this is sufficient for masonry structure and provides a more economical and environment- friendly alternative that is accessible to every section of the society. However, there is still ample scope for research on the subject. [1]

In this research paper titled "**Analysis of bamboo reinforced concrete column**", Ajinkya Kaware1, Prof. U.R.Awari, and Prof. M.R.Wakchaure represent that design and testing of Bamboo reinforced concrete column to be casted with bamboo reinforcement varying from 2.5 % to 4 % at an increment of 0.5 with 3 rectangular specimen of size 230 x 150 x 750 mm3, 3 specimen of square column 150 x 150 x 750 mm3 and 230 mm diameter and 750 mm length 3 circular specimens for each increment in reinforcement. Above mentioned column are compared with steel reinforced concrete column of similar dimension, numbers and shape with minimum steel reinforcement. [2]

In this research paper titled "**Bamboo reinforced concrete: a critical review**", Hector Archila, Sebastian Kaminski , David Trujillo, Edwin Zea Escamilla and Kent A. Harries addresses such 'bamboo-reinforced concrete' and assesses its structural and environmental performance as an alternative to steel reinforced concrete. A prototype three bay portal frame, that would not be uncommon in regions of the world where bamboo reinforced concrete may be considered, is used to illustrate bamboo reinforced concrete design and as a basis for a life cycle assessment of the same. The authors conclude that, although bamboo is a material with extraordinary mechanical properties, its use in bamboo-reinforced concrete is an ill-considered concept, having significant durability, strength and stiffness issues, and does not meet the environmentally friendly credentials often attributed to it. [3]

In this research paper titled "**Bamboo as reinforcement in structural concrete elements**", Khosrow Ghavami states that the results of some of the recent studies of the microstructure of bamboo as a functionally gradient material. These studies led to the establishment of bamboo's composite behaviour through the rule of mix. A concise summary regarding bamboo reinforced concrete beams, permanent shutter concrete slabs and columns is discussed. Finally, some recommendations for future studies are proposed with the hope that the newly developed material could contribute, on a large scale, to sustainable development without harming our globe. [4]

In this research paper titled "**Bamboo reinforced concrete beam – step toward sustainable development**", Vijay R Wairagade, Ishwar P Sonar state that Engineer's role is to provide the best facilities at optimum cost. And as such Concrete is the most consumed construction material in the entire world because of its various advantages such as low cost, availability, easy to mould, good compressive strength, fire resistance etc. But it cannot be used alone because of its low tensile strength. And therefore it is usually reinforced with steel which is very strong in tension. Authors have tried to explore the structural behaviour and the future applications of bamboo reinforced beam for a low cast housing preferably in rural areas where bamboo is available in abundant as a step towards sustainable development. [5]

In this research paper titled "**State of The Art: Bamboo as a Structural Material**", M. B. Varma finds suitability of bamboo as a structural member. Many research workers have studied different properties of bamboo. They have presented properties which attract attention of structural engineer to try and use bamboo, bamboo strips in structural elements. Bamboo is light in weight, easily available and available in ample and also unskilled workers can handle very easily, with vary less cost, so may fulfill requirements of good building material. [6]

In this research paper titled "**Fracture Behavior and Mechanical Properties of Bamboo Reinforced Concrete Members**", Masakazu TERAI AND Koichi MINAMI state that the seismic retrofit of the masonry structures in the design and construction of bamboo reinforced concrete. A study of the feasibility of using bamboo and non-steel as the reinforcing material in concrete members was conducted in our laboratory. Six beam specimens were constructed and a total of 11 beam tests were performed to examine the flexural cracking and the shear cracking strength. Additionally, monotonic compression tests were carried out on 16 column specimens, which has 200mm in diameter and 500mm in height with confining steel bars or PP-band spirals, in order to study fracture behavior and mechanical property of bamboo confined concrete. [7]

In this research paper titled "**Experimental Analysis of Bending Stresses in Bamboo Reinforced Concrete Beam**", Dinesh Bhondea, Dr P. B. Nagarnaik, Dr D. K. Parbat, Dr U. P. Waghe say that Bamboo has been a very fascinating natural material useful in almost all aspects of life. Bamboo is a light weight, tensile, flexible, sustainable, eco friendly, green material and its use shall be advocated in building construction for sustainable development. Author evaluates bamboo reinforced concrete beam with four point loading. The load elongation curve was plotted and load at first crack, ultimate bending moment at failure was studied. The values of maximum bending stresses at extreme concrete fibre and the concrete surrounding reinforcement were found. Ultimate experimental stresses, design stresses were compared. [8]

In this research paper titled "**The Recent Research on Bamboo Reinforced Concrete**", Sri Murni Dewi and Devi Nuralinah say that three kinds of structures studied in recent year, the mounting of pegs on reinforcement, the use of lightweight brick to reduce the weight of the beams, and the use the light weight aggregate for bamboo concrete composite frame. All that experiments overcome some problems exist in using bamboo as environmental acceptance structures. [9]

3. EXPERIMENT

3.1 - Tensile Strength Test

Laboratory experiment was carried on the specimen of **Manga** (Dendrocalamus Stocksii) and **Dagdi** (Bambusa Balcooa) Bamboo under the UTM (Universal Testing Machine).

Process -

1. Selection of bamboo -
   - First the whole bamboo samples were collected in the length of 1m.
   - Then the samples were split into 4 parts using chisel and further split into half, which means 8 parts in total.
   - Sample contained atleast 2-3 knots.
   - Any undulation was trimmed off using carpentry tools like chisel.

Fig -3: Bamboo samples of Dagdi Bamboo

Fig -4: Bamboo samples of Manga Bamboo

2. Treatment on bamboo -

- The treatment on the sample has to done to have a good bond strength when in contact with concrete.
- Bitumen Layer of Tar is spread over the sample properly using the brush.
- Rangoli spread over the sample after tar, evenly to achieve the roughness.
- Gloves to be used for precaution measures.

Fig -5: Treatment material and specimen after layer of tar

3. Drying -

- Keep the sample for drying under the sun for atleast 2-3 days.
- Keep it rotating so that all sides are dried up properly.

Fig -6: Specimen kept for drying under sun

4. Specimen ready -

- The bamboo samples of 1m in length are cut into 60 cm as per the UTM requirements for a specimen.
- Sample contained atleast 1-2 knots.
- Any undulation was trimmed off using carpentry tools like chisel.

Fig -7: Specimen cutting and chiseling off

5. Final Stage -

- Bamboo (Manga & Dagdi) specimen of 60 cm are ready.
- Specimen's are covered by doctor tape 10 cm on both sides for holding as a grip in the UTM machine.

Fig -8: Manga and Dagdi Specimen with grip

3.2 - Compression Strength Test

3 cubes (150 x 150 x150) were casted with a mix proportion design which undergo the UTM for the compression test after 28 days curing period.

Process –

1. Moulds -

- Cube Casting steel moulds were brought on site from the testing lab.
- Some nuts, bolts and wrench brought from the hardware to tighten the cube mould from all sides to maintain its shape once concrete is poured.
- All 3 moulds were completely oiled up from the inner side to smoothen its removal once concrete is dried up.

Fig -9: Cube casting module's

2. Concrete -

- Concrete was prepared by the labour on the site.

- OPC (Ordinary Portland Cement) Birla shakti cement of 53 grade was used.
- According to mix proportion design other ingredients like water, sand and aggregate were used.
- The Mix proportion design varied for a beam and cube as per reinforcement and quantity for both.

3. Casting -

- The prepared concrete mix was then poured into the moulds.
- Once poured it was manually vibrated with a steel rod so that the extra slurry is removed off and the concrete is leveled that of the mould.

Fig -10: Preparation of concrete and casting

4. Concrete Cubes -

- Concrete casted in the moulds of cube were kept for 24 hours or more, so it will be well settled and dried up.
- As the moulds were oiled from the inner side and some tighten nuts and bolts were loosened by wrench, the casted cube were easily removed.
- Casted cubes once removed were neat and clean in exact shape as expected.
- Cubes were further kept in a water tank for 28 days of curing period.

Fig -11: Concrete cubes dried and ready for curing

3.3 - Flexural Strength Test

Laboratory experiment was carried on the specimen of Manga (Dendrocalamus Stocksii) and Dagdi (Bambusa Balcooa) Bamboo under the UTM (Universal Testing Machine). In Total 5 beams of (150 x 150 x 700) were casted which are as follows,

2 Beams - Manga Bamboo, 2 Beams - Dagdi Bamboo and
1 Beam - Conventional Steel

and kept for 28 days of curing which will then undergo UTM to check its flexural strength.

Process -

1. Reinforcement -

- All the treated bamboo cut down to size of length 640 mm as leaving 30mm cover on both sides were brought on site. Which will replace steel in place of reinforcement.
- Steel bar of 8mm for stirrups was made available on site.
- Binding wire to bind the treated bamboo and the stirrups.
- Measuring tape to maintain exact centre to centre 100mm dimension distance between the stirrups.
- Repeat the same procedure for all 5 beams.

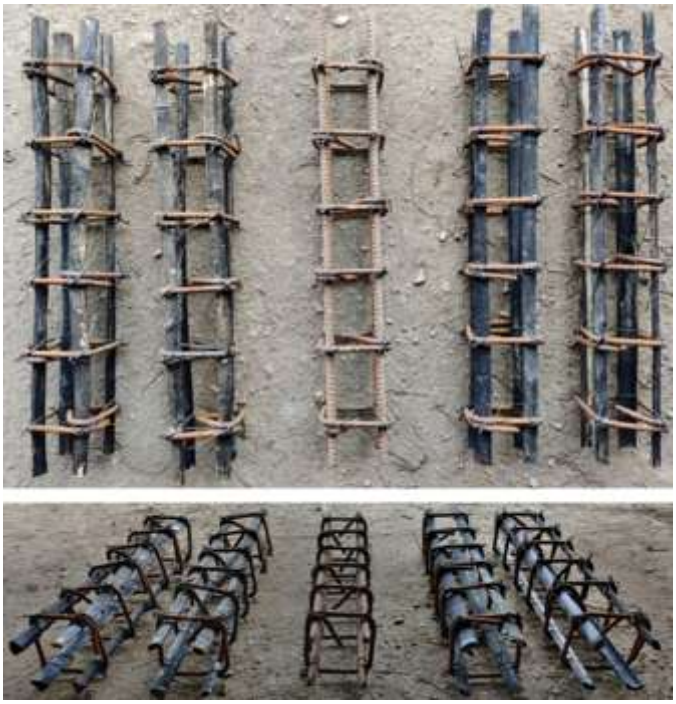

Fig -12: Reinforcement ready for all 5 beams

2. Moulds -

- Beam Casting steel moulds (150 x 150 x 700) were brought on site from the testing lab.
- Some nuts, bolts and wrench brought from the hardware to tighten the beam from all sides to maintain its shape once concrete is poured.
- All moulds were completely oiled up from the inner side to smoothen its removal once concrete its settled and dried up.

3. Concrete -

- OPC (Ordinary Portland Cement) Birla shakti cement of 53 grade was used.

- Mix proportion design other ingredients like water, sand and aggregate were used.
- The Mix proportion design varied for a beam and cube as per reinforcement and quantities for both.

4. Casting -

- The prepared concrete mix was then poured into the moulds.
- Once poured it was manually vibrated with a steel rod so that the extra slurry is removed off and the concrete is leveled to that of the mould.
- Marking on the specimen was also done as M1 for Manga 1, D1 for Dagdi 1 etc.

Fig -13: Reinforcement ready for all 5 beams

5. Beams -

- Concrete casted in the moulds with Bamboo reinforcement and Steel reinforcement were kept for 24 hours or more, so as to get well settled and dried up.
- As the moulds were oiled from the inner side and some tighten nuts and bolts were loosened by wrench, the casted beams were easily removed.
- Casted beams once removed were neat and clean in exact shape as expected.

6. Curing -

- All 3 Cubes and 5 beams casted were further kept in a sintex flat water tank of 100 litre storage capacity for 28 days of curing period.
- No disturbance at all for the 28 days.
- 3 Cubes and 2 beams were casted on the first day and following beams on the consecutive days.

Fig -14: Reinforcement ready for all 5 beams

4. TEST RESULTS

4.1 - Tensile Strength - Results of Bamboo specimen
A) Breaking point of **MANGA** (Dendrocalamus Stocksii)
Specimen 1 - 40.60 KN *(40600 N)*,
Specimen 2 - 41.30 KN *(41300 N)*

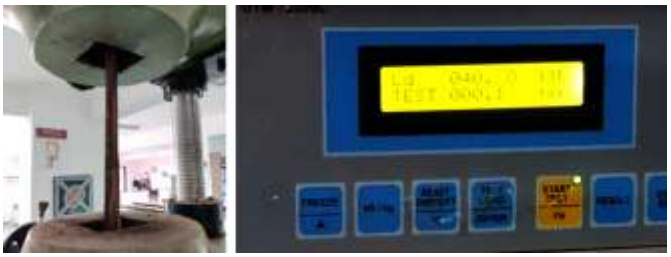

Fig -15: Manga bamboo specimen under UTM and readings

B) Breaking point of **DAGDI** (Bambusa Balcooa) Bamboo -
Specimen 1 - 37.30 KN *(37300 N)*
Specimen 2 - 38.60 KN *(38600 N)*

Fig -16: Dagdi bamboo specimen under UTM and readings

Tensile strength, $\sigma = P/A$
Where, $P =$ KN x 10^3

$$A = \frac{\pi}{4} \times d^2$$

$$\therefore d = \sqrt{\frac{260 \times 4}{\pi}}$$

$$= \sqrt{\frac{1040}{3.14}}$$

$$= \sqrt{331.21} = \mathbf{18.19\ mm}$$

Further, Bamboo (18-20 mm) used as reinforcement in the beams replacing 18 mm steel.

Table- 1: Bamboo specimen's tensile test results

Common Name	Specimen	Peak Load (N)	Area (mm2)	Tensile Strength (mpa)
Dendrocalamus Stocksii (Manga)	M1	40600	260	156.15
Dendrocalamus Stocksii (Manga)	M2	41300	260	158.85
Bambusa Balcooa (Dagdi)	D1	37600	260	144.62
Bambusa Balcooa (Dagdi)	D2	38600	260	148.46

The Tensile strength of Manga & Dagdi bamboo can be seen in the above table. If compared with tensile strength of structural steel or threaded steel bar is above 400 mpa.

4.2 - Compressive Strength -

Results of **Concrete Cube** specimen - (150 x 150 x 150)
Breaking point of Specimen C1 - **420.35 KN**

Fig -17: Specimen C1 with reading

Breaking point of Specimen C2 - **450.60 KN**

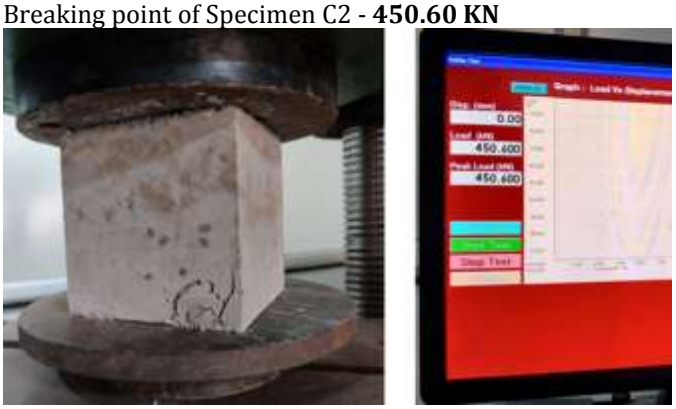

Fig -18: Specimen C2 with reading

Breaking point of Specimen C3 - **463.05 KN**

Fig -19: Specimen C3 with reading

Compressive Strength, **C.S** = $\frac{L}{A}$,

where, L = Peak Load
A = Area

Sample C1 - $\frac{420.35 \times 10^3}{150 \times 150}$ = **18.68** N/mm²

Sample C2 - $\frac{450.60 \times 10^3}{150 \times 150}$ = **20.02** N/mm²

Sample C3 - $\frac{463.05 \times 10^3}{150 \times 150}$ = **20.58** N/mm²

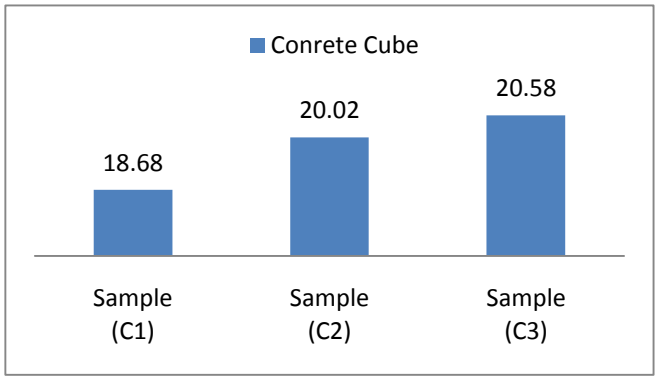

Chart -1: Compression strength testing result

The average of concrete cube tested comes to 19.76 N/mm² Therefore, Considering M20 good for construction further tests were carried out.

4.2 - Flexural Strength -

Results of **BRCC** BEAM specimen - (150 x 150 x 700) after Curing Period of 28 Days.

Manga (M1) - **26.90 KN** *(26900 N),*
Dagdi (D1) - **32.35 KN** *(32350 N)*

Fig-20 : D1 BRCC beam breaking point with reading

Manga (M2) - **27.45 KN** *(27450 N)*
Dagdi (D2) - **33.45 KN** *(33450 N)*

Fig -21: M2 BRCC beam breaking point with reading

SRCC Beam (SB) - **62.40 KN** (62400 N)

Fig -22: SB SRCC beam breaking point with reading

Flexural Strength, **F.S** = $\frac{P.L}{bd^2}$,

where P = Load at Failure
L = Span
bd² = width & Height²

M1 = $\frac{26.90 \times 10^3 \times 600}{150 \times 150^2}$ = **4.78** N/mm²

D1 = $\frac{32.35 \times 10^3 \times 600}{150 \times 150^2}$ = **5.75** N/mm²

M2 = $\frac{27.45 \times 10^3 \times 600}{150 \times 150^2}$ = **4.88** N/mm²

D2 = $\frac{33.45 \times 10^3 \times 600}{150 \times 150^2}$ = **5.94** N/mm²

SB = $\frac{62.40 \times 10^3 \times 600}{150 \times 150^2}$ = **11.09** N/mm²

Relation between **F.S** and **C.S**

F.S = $0.7\sqrt{fck}$

= $0.7\sqrt{20}$ **= 3.13** N/mm²

Minimum strength required is 3.13 N/mm² which is easily achieved in all the above specimens tested above.

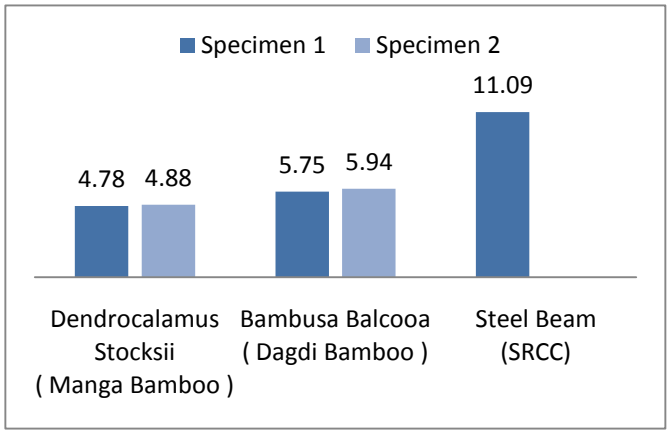

Chart -2: Flexural strength beam testing results

5. CONCLUSIONS

All the experiment were carried in a testing laboratory on universal testing machine (UTM) capacity of 1000 KN (100 ton). The Tensile strength of Manga & Dagdi bamboo if compared with strength of steel bar is half, but it was further tested by flexural strength experiment. For the compression test 3 cubes of size 150 x 150 x 150 were casted and after 28 days of curing the cubes were properly dried and test was conducted were average of all 3 cubes was 19.76 N/mm² hence considering M20 grade of concrete good for construction. For the flexural test 5 beams were casted in which 2 specimen each for Manga and Dagdi bamboo were casted in comparison with conventional reinforcement beam size of 150 x 150 x 700, the result clearly showed that the average of Manga bamboo specimen is (4.83 N/mm²) less than that of Dagdi bamboo (5.84 N/mm²). The conventional beam in comparison showed the result as 11.09 N/mm².

Thus the minimum requirement for flexural strength is 3.13 N/mm² for M20 grade of concrete, which is easily available in bamboo reinforced concrete. But in comparison of steel reinforced concrete results are approximately 3 times higher and stronger. Thus one can recommend that bamboo reinforced concrete can be executed atleast to some extent for G+1 structures or low cost G+1 housing projects (as composite reinforcement), in such way the cost of construction can also be reduced.

ACKNOWLEDGEMENT

This study would not have been possible without the support of the institute Dr. D.Y. Patil College of Architecture, Akurdi, Pune. Author is extremely grateful to the guides Mr.Sudhanshu Pathak and Mr. Mahesh Tatikonda for their time to time valuable insight and support in completing this study.

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