

BAMBOO ASA REINFORCEMENT IN STRUCTURAL CONCRETE ELEMENT**Shinde Suryakant Shashikant*¹, Gaikwad Sarang Eknath*², Daunde Aniket Nandu*³,
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ABSTRACT

Traditionally steel is employed as reinforcement in concrete. however due to value and handiness, rather than steel with another appropriate materials as steel is currently a significant concern. Bamboo is one among the oldest and most versatile building materials with several applications within the field of construction, significantly in developing countries, it's sturdy and light-weight and might usually be used while not process or finishing. The decreasing wood resource and restrictions imposed on felling in natural forests, significantly in the tropics, have targeted world attention on the necessity to spot a substitute material that ought to be renewable, ecofriendly and wide out there. In view of its ascent (exceeding most quick growing woods), a prepared ability to most climatically and edaphic conditions and properties superior to most juvenile quick growing wood, bamboo emerges as a very suitable various. However, so as to completely exploit the potential of bamboo, development effort ought to be directed at the key areas of preservation, jointing, structural style and codification. additionally, socioeconomic, appropriateness and technical studies will be essential to spot factors that govern current bamboo usage, and people which is able to influence its use in the longer term. Once these problems have been addressed, bamboo are going to be ideally placed to become a principal engineering and construction material for the twenty 1st century and on the far side.

Keywords: Semitropic, Cellulose, Compression.

I. INTRODUCTION

Infrastructural growth is resulting in fast environmental degradation. Steel, cement, artificial polymers and metal alloys used for construction activities square measure energy intensive similarly as cause environmental pollution throughout their entire life cycle. to handle this issue, analysis on non-polluting materials and producing processes are obsessed within the recent years. during this analysis, use of bamboo that is quick growing and ecologically friendly material for structural applications particularly in an exceedingly tropical country like Bharat is being thought about as quite applicable.

The shortage of housing in developing countries motivates the look for low value materials which will be applied within the construction of cheap homes for poor peoples. several researchers are finding out the applying of the domestically bumper natural materials as building materials like mud blocks, natural fibers reinforcing soil or cement matrixes and bamboo culms. These materials and therefore the ancient building techniques, which just about have nonexistent once the wide implementation of the building business, square measure the most focus of the researchers on non-conventional materials and techniques at the current time of environmental crisis, that our globe is facing. In recent years the demand for structural wood product for building materials has magnified with increasing construction of housing. On the opposite hand, the number and quality of wood resources from the forest are decreasing.

Consequently, the look for substitute materials in situ of the standard uses of wood has been the main focus of revived interest Bamboo. specifically, is taken into account a promising alternate material owing to its quick rate of growth, short rotation age, and high lastingness. magnified analysis during recent years has contributed considerably to the understanding of these important grasses and to improve processing for wider use. There is perpetually would like of low value mass housing schemes for earthquake affected areas, emergency structures and temporary structures in several things. Use of prefab and pre-cast structural members is one choice to save the price and time. it's conjointly discovered that for lightweight loading or brief span structures, strength properties of concrete members like block, beams and columns don't seem to

Be totally utilized even if they're provided as per the wants of minimum dimensions and structural materials. Therefore, through to save expensive standard materials by exploitation applicable style of the member and appropriate economical material. With the aim to utilize strength properties of bamboo in concrete column a hunt project work is undertaken on bamboo bolstered hollow circular column.

Bamboo reaches its full growth in mere a couple of months and reaches its most mechanical strength in mere few years. Its abundance in tropical Associate in Nursing semi tropic regions makes it an economically advantageous material. a number of the positive aspects like a light-weight style, higher flexibility, and toughness because of its skinny walls with discretely distributed nodes and its nice strength create it a decent construction material. Bamboo is employed as structural material for system at construction sites in India, China and alternative countries because it may be a powerful, flexible, light-weight weight and low value material. In nature once bamboo is roofed with serious snow, it'll bend till it touches the bottom while not breaking. The energy necessary to supply one M3 per unit stress projected in observe for materials normally employed in civil construction, like steel or concrete, has been compared with bamboo.

It had been found that for steel it's necessary to pay fifty times a lot of energy than for bamboo". The strength of bamboo is extremely high and may reach (370 N/mm²). This makes bamboo an alternate to steel in tensile loading applications. this is often because of the actual fact that the magnitude relation of strength to specific weight of bamboo is sixfold larger than that of steel (Amanda et al. 1997). Steel reinforcement at some purpose might not be on the market. Even nowadays there exist a requirement for a lot of economical and without delay on the market substitute reinforcements for Concrete. In some components of the globe several buildings square measure created solely with concrete or mud-bricks. this is often dangerous just in case of unstable activity.

II. LITERATURE REVIEW

This literature review spanning the range of physical and mechanical properties of bamboo and bamboo as reinforcement in structural element.

2.1 BAMBOO AS REINFORCED ELEMENT – REVIEWED BY RESEARCHERS

2.1.1 Ranendra Nath Bhowmik, "An Experimental Study on Behavior of Bamboo Reinforced Brick Aggregate Concrete Beam" (2017)- (INDIA- TRIPURA)

In the above experimental study an attempt has been made to check the technical feasibility of utilizing Bambusa Balcooa as a reinforcing material in brick aggregate concrete structure. Different tests were conducted to evaluate different properties related to bamboo reinforced beam. Based on the results of those tests a brief conclusion is presented.

2.1.2 S. Karthik, 'Strength properties of bamboo and steel reinforced concrete containing manufactured sand and mineral admixtures' (2017) – (UAE)

From the morphological (FTIR and SEM) characteristics of bamboo dust examined, it was deduced that bamboo is a ductile reinforcing material having some appreciable tensile strength, which makes it suitable as a substitute for steel. Due to its strongly bonded particles, bamboo can be an excellent material for members subjected to compression and bending.

2.1.3 Sri Murni Dewi¹, 'The Recent Research on Bamboo Reinforced Concrete' (2017) – (INDONESIA)

The-use-of-bamboo-for-environmentally-friendly-construction-material-additional quickly enforced and Supplement price in-terms-of value and-environmental property is utilization of pegs on the beam is in a position to feature tensile load bearing capability reinforcement. additional pegs reinforcement adds increase effective stress of forty five MPa to ninety MPa. the utilization of pegs on reinforcement like hooks on the steel reinforcement are a chance to form a rigid beam-column affiliation. Another style of pegs was fascinating for following analysis. the utilization of light-weight materials is incredibly advantageous for formed structures and earthquake-resistant structures. the utilization of construction and industrial waste is profit visible of Environmentally friendly. The analysis was command and supported by Ministry of analysis Technology and-better Education-Republic- of Indonesia incredibility fascinating to additional studied.

2.1.4 , Suresh Kumar, 'A Study on Bamboo Reinforced Concrete Slabs' (2016)- (CHENNAI)

Thus the bamboo may be used as a attainable replacement of steel within the trendy engineering constructions. The durability of bamboo is comparatively high that makes bamboo a lovely different to-steel-in-tensile-loading- applications. Thebamboo ferroconcrete blocks andsteel ferroconcrete block ar havinghigh tensile stress than traditional concrete while not reinforcement. At constant time the deflection of the each slabs aremerely equal at 40KN load. in order that steel will be replaced with bamboo in lowest loading for structural applications.

2.1.5 Abhijeet Dey, 'Experimental study of Bamboo Reinforced Concrete beams having various frictional properties ' (2016) – (INDIA)

Many researches has been disbursed during this field that helps United States in understanding that use of bamboo in ferroconcrete includes a huge scope. From the experimental work it are often finished that bamboo provides a high lastingness of 250 N/mm² or higher that all depends on the realm of cultivation, sort of species and cross-sectional space. associate degree improved flexural performance of BRC beam has been ascertained with the rise in variety of days of solidification amount and increase within the size of bamboo rebar. it's conjointly counseled to use steel stirrups because it improves the flexural moreover as shear capability of beam. though the aim of the study is to extend the flexural strength however in sensible case with the rise in span of the beam the middle span deflection will increase that is additionally a crucial criterion once usefulness limit state is taken into account, therefore reduction of middle span deflection is another major space of analysis.

2.1.6 Javadian, Alireza, 'Bamboo Reinforcement – A Sustainable Alternative to Steel' (Oct -2014) – (SINGAPORE)

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 for structural concrete, doesn't solely come back together with vast environmental edges (e.g. the reduction of carbon footprints) however associate Brobdingnagian socioeconomic impact has. Considering the actual fact that the herein conferred reinforcement system will truly be made inside those territories, that square measure less-developed however expect the-very-best demand-for-building material inside succeeding decades-materials inside succeeding decades, actuality plus isn't a-brand-new property material technology however the creation of social equity. associate rising native trade would be ready to satisfy the artefact demand and, additionally, produce new price chains for the rising economies within the developing world. Hence, actuality innovation of this analysis isn't the creation and application of a brand new material that may function an alternate to steel in terms of mechanical properties however – most significantly – additionally as an alternate seeable of world socio-economic aspects.

2.1.7Dr. ShakeelAhmad , 'Mechanical Properties of Bamboo Fibre Reinforced Concrete' (2014) – (UAE)

Modulus of elasticity of concrete increases by addition of bamboo fibres. The flexural strength of bamboo reinforced beam increases as high as nearly doubled, so bamboo reinforced beam can be used in low cost buildings. Bamboo fibres can be used as replacement with concrete which can save the expensive concrete, 10000cm³ per 1m³ of concrete.

2.1.8 I.K. Khan, ' PERFORMANCE OF BAMBOO REINFORCED CONCRETE BEAM ' (2014) – (INDIA)

Flexural and shear strength was higher in bamboo reinforced beam with square cross section as compared to triangular and circular bamboo sections. These were about 50% less than steel reinforced concrete beam. Based on the limited number of test conducted, it was concluded that Bamboo may be used as substitute of steel reinforcement in beams. However, for regions of the world where availability of steel is limited and plain concrete members are commonly being used.

2.1.9 Anurag Nayak , 'Replacement of Steel by Bamboo Reinforcement '(2013)- (INDIA)

In this project we have opted advanced bamboo reinforcement technique instead of traditional steel reinforcement. This is a good idea for low cost economical structure. Bamboo reinforcement technique is used for both main and distribution reinforcement as it was same earlier done for steel reinforcement. It is three

times cheaper than steel reinforcement technique. It is clear from results that this bamboo reinforcement technique is absolutely cheaper than steel reinforcement technique especially for single story structure.

2.1.10 Prof. M.R. Wakchaure, 'REVIEW OF BAMBOO AS REINFORCEMENT MATERIAL IN CONCRETE STRUCTURE' (2013) - (MAHARASHTRA)

Bamboo has wonderful engineering properties and might be used for low value public housing. It will principally be used as reinforcement to the structure. Disadvantage of bamboo as construction material is its water absorption and wet content properties. This principally affects its strength. To cut back this impact seasoning and correct coating to bamboo ought to be done before victimization it for reinforcement.

2.1.11, Prof. M.R. Wakchaure, 'ANALYSIS OF BAMBOO REINFORCED CONCRETE COLUMN' (JUNE- 2013) - (MAHARASHTRA)

Proper craftsmanship and skillful management helps in obtaining want strength. Compaction of concrete ought to be adequate alternatively honey combed structure square measure created. Bamboo reinforcement ought to be coated with black Japan because it has smart water repellent and bond quality. Bamboo ought to season for a minimum of half dozen months before mistreatment it as reinforcement. Bamboo reinforcement shouldn't be exposed to atmosphere because it created defects like swelling and decay. For lateral dimension but 230 millimeter 2 totally different confinements of bamboo reinforcement and concrete cover occur. Because it doesn't maintain individualism in style we discover 2 totally different failure patterns of reinforcement and outer cowl. Load displacement and stress strain curves in bamboo reinforced column show typical pattern as in steel reinforced column. For low price housing comes bamboo reinforced structure is possible and provides desired strength.

2.1.12. Chetan S. Agrawal, 'Study on Bamboo as Reinforcement in Cement Concrete' (2013) - (INDIA - GUJRAT)

Based on the experimental study the modulus of elasticity of Doubly Reinforced Beams more than twice of the Singly Reinforced Beam. Modulus of elasticity for Singly Reinforced Beams 3, 762.94 N/mm². Modulus of elasticity for Doubly Reinforced Beams 14, 597.70 N/mm².

2.1.13. Koichi MINAMI, 'Research and Development on Bamboo Reinforced Concrete Structure' (2012) - (JAPAN)

The availability of combination bamboo and concrete structure can be confirmed. Therefore, for construction of the actual structure, it is necessary to verify some realistic methods. 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 contemplate the sensible application. For employment of the structure with bamboo, it appears to be vital to contemplate the conditions: style of the structure with bamboo, mixtures of materials (the concrete strength and sort of bamboo), Construction and Workability and, sturdiness of bamboo inside mortar and concrete.

2.1.14. M.R. Wakchaure, 'EFFECT OF MOISTURE CONTENT ON PHYSICAL AND MECHANICAL PROPERTIES OF BAMBOO' (2012) - (NASHIK)

Bamboo is one in all the replenishable, low value and low energy intensive, extreme product of nature that is employed as construction materials in hut kind dwellings in developing countries and is additionally well established supply of paper pulp. The utilization of bamboo for housing is maybe as recent as grouping, however, the superior strength and mechanical properties of bamboo and its potential to be used as reinforcement for cement matrices started at the start of twentieth century. This was followed by many field applications in China it's proverbial that in the Second warfare, the Yank and Japanese military had used bamboo reinforcement in emergency military structures. Bamboo could be a natural stuff that grows profusely in most of the tropical countries. It's thought of as a stuff as a result of it consists of polyose fibers imbedded during a polymer matrix. Polyose fibers square measure aligned on the length of the bamboo providing most tensile flexural strength and rigidity in this direction.

III. METHODOLOGY

PHYSICAL AND MECHANICAL PROPERTIES

Like different plants, bamboo possesses terribly high wetness content. Recent cut inexperienced bamboo might have one hundred percent wetness on dry weight basis. wetness Content (MC) are often as high as a hundred and fiftieth for the innermost layers to seventy % for the peripheral layers. The vertical variation from the highest (82%) to rock bottom (110%) is relatively less. Abd. Latif noted in 1993, that the MHz vary of monocot genus blue meana is 57-97% which for genus Dendrocalamus strictus is 55-95%. The wetness content of bamboo varies vertically from rock bottom to the highest parts and horizontally from the outer layer to the inner layers . not like wood, bamboo has no secondary growth; all gains once it reaches its full height area unit because of the addition of fabric to cells once the primary year. Fibers in bamboos area unit sorted in bundles and sheaths round the vessels. The dermal walls accommodates AN outer and inner layer; the latter of that is very woody. Fiber length and fiber breadth varies inside one segment. Fiber proportion is higher within the outer one- third of the wall and within the higher a part of the stem, causative to its superior slenderness as rumored by Grosser and Liese in 1971. relative density of the peripheral layers is over the inner layers in any respect height locations of bamboo. 60-70% of the whole weight of bamboo is that the contribution of four-hundredth fibers that area unit solely by volume, rest is by parenchyma and vessels and capillaries. the precise gravity of bamboo varies between zero.4 and 0.8 relying in the main on the structure and also the species.

The physical and mechanical properties of bamboo vary with the age of the bamboo and the height of the culm. Species of bamboo in tropical belt shows maximum strength at third to fourth year of age . It is found that older culms of Dendrocalamus strictus became 40- 50 percent stronger and stiffer than young ones .

Strength Properties of Bamboo

It has also been found that bamboo acts very well in buckling but due to low stresses than compared to steel and due to it not being straight it may not be very good. Further, it has been established that in seismic zones the failure of bamboo is very less as the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo which is the main source of mechanical properties of bamboo.

Some specific properties of Bamboo are as given below:

- Specific gravity - 0.575 to 0.655
- Average weight - 0.625kg/m
- Modulus of rupture - 610 to 1600kg/cm²
- Modulus of Elasticity - 1.5 to 2.0 x10⁵kg/cm²
- Ultimate compressive stress- 794 to 864kg/cm²
- Safe working stress in compression - 105kg/cm²

Behavior in Tension:

The chosen bamboos were divided into splints which are further shaped as specimens for tension test. The splints were shaped so as to have uniform width throughout without disturbing the inner and outer curvatures. The area of cross section of the specimen was kept low to avoid slippage at tabs at the ends or grips of the tension testing machine as shown in Figure 1.



* Tension test specimen with and without node, with end tabs *

The material structure of bamboo isn't uniform on the length because of nodes. Also, the data given in literature referred to this point with regards to, the result of the node on enduringness of bamboo, found to be restricted and thus it absolutely was desired to check this result. 1/2 the specimens were taken from inter-

nodal zone and remaining from the nodal region. Specimens extracted from basal, middle and prime a part of bamboo were tested. Care was exercised whereas making ready samples with nodes in order that a node was at the middle of the gauge length. To avoid crushing of bamboo at intervals the grips of the Universal Testing Machine (UT100), metallic element tabs were affixed to the specimen within the grip length.

Behavior in compression:

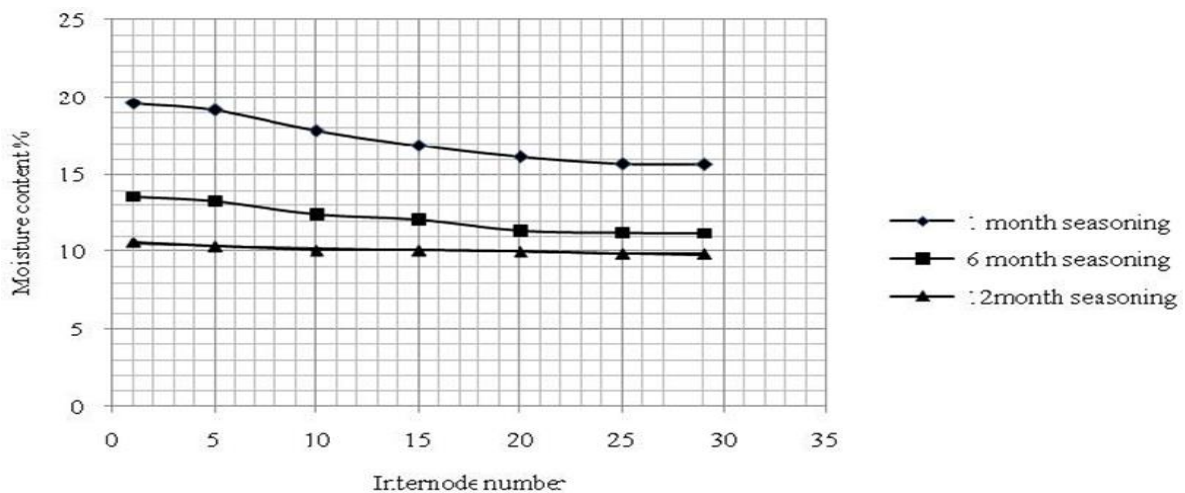
The compression check were distributed on whole bamboo specimen having length, eight times the thickness of bamboo as per Indian customary [13, 14] with some modifications shown in Figure a pair of. Samples made up of the internodes and having nodes from completely different height locations for one, six and twelve months seasoning were used. The compression check parallel to grain was performed with whole bamboo samples mistreatment identical machine (UT100). the consequences of wet content, height, and presence of



*** Compression test specimen from internode region before and after the test ***

Moisture content and specific gravity .

Moisture content is a crucial parameter of bamboo. It governs the mechanical properties and Plays important role to decide lifetime of bamboo. ordinarily inexperienced bamboo has average sixty to seventy Fifth wet content relying upon the age, season, geographical location, species and watering ways. there's a powerful relation between insect attacks and also the levels of starch and wetness content of bamboo stalk. Drying bamboo is prime to its conservation for numerous reasons. Bamboos square measure seasoned by air drying keeping in vertical position. The wet content reduces from bottom to high for inexperienced furthermore as bamboo in the least stages of seasoning. The variation of wet content on the peak for representative bamboo is bestowed in Graph below.



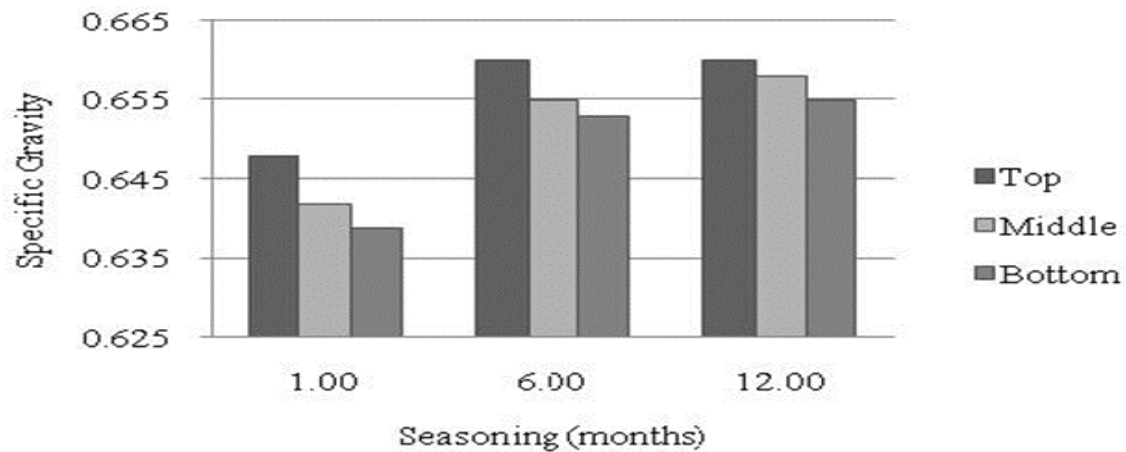
Variation in moisture content

Bamboo with low humidness is a smaller amount at risk of mould attacks particularly once humidness content is a smaller amount than 15 August 1945. Physical and mechanical properties of bamboo increase with a decrease in its humidness content. The wet content and relative density of air dried bamboo for various

locations and seasoning periods area unit listed in Table no Three density supported kitchen-appliance dried mass doesn't show abundant variation on height or air drying amount, prime parts systematically had higher relative density than the center and bottom portion for every stage of seasoning. All results area unit calculated at the wet content-mentioned-in-Graph a-pair-of

Table 3: Moisture content and specific gravity

Seasoning period (Month)	Location	Moisture content (%)	Specific gravity
One	Top	16.09	0.648
	Middle	17.35	0.642
	bottom	19.13	0.639
Six	Top	11.38	0.660
	Middle	12.09	0.655
	bottom	13.46	0.653
Twelve	Top	9.98	0.660
	Middle	10.05	0.658
	bottom	10.31	0.655



Comparison between bamboo & steel

One of the properties that will create bamboo a decent substitute to steel in concrete is its strength. The strength of bamboo is bigger than most timber merchandise that ar advantageous, however it's more or less 0.5 the enduringness of steel. Bamboo is well accessible because it grows in nearly each tropical and climatic zone region, this lowers the price of construction and will increase the strength of the buildings that will well be unreinforced. One major downside with bamboo is that it attracts living organism like fungi and insects. Bamboo is a lot of vulnerable to insects than different trees and grasses as a result of it's a high content of nutrients. so as to combat this downside, it becomes necessary to treat bamboo to safeguard it from the atmosphere. Steel doesn't have this downside however it conjointly has to be coated so as to safeguard it from oxidisation. Bamboo is extremely light-weight in weight compared to steel. because of its low modulus of snap, bamboo will crack and deflect over steel reinforcement beneath an equivalent conditions. These aspects place bamboo on the list of viable construction materials. These properties, once combined, recommend that bamboo can create a fine addition to this choice of materials, however it's necessary that folks normally be created a lot of accustomed to its strengths and weaknesses.

BAMBOO REINFORCED CONCRETE COLUMNS

The development of science & technology could be a continued look for improvement in infrastructure of world around United States. The structures in nature area unit nice lessons for human study solely the foremost eco-friendly structural forms have survived. The profound capability answer a range of environmental condition and environmental forces, makes a natural style of tremendous exemplars to varied fields of structural style. A natural material that is out there in bulk and easy use within the rural areas within

the developing countries is bamboo. Bamboos occur largely in tropical and semitropical areas, from water level to snowcapped mountain peaks, with a couple of species reaching into temperate areas.

In order to conduct the compression tests, it absolutely was necessary to style the axially bamboo strengthened column varied from a pair of.5 you have to four to try Associate in Nursing increment of zero.5 you tired of three rectangular specimen of size 230 x one hundred fifty x 750 mm³, three specimen of sq. column one hundred fifty x one hundred fifty x 750 millimeter³ and 230 millimeter diameter and 750 mm length three circular specimens for every increment in proportion. The concrete used was of M twenty grade and steel used was metallic element five hundred MPa. The bambooused was of genus Dendro calamus strictus (so species and its compression strength was administered through an experiment victimization IS 6874: 1973 was sixty six MPa. The columns were designed as per IS 456: 2000. First, the bamboo samples were move the right size and form. The thickness, together with the breadth, differed between the samples as a result of Bamboo may be a natural material whose physical properties vary. For this reason a careful orienting of the sample was done before utilizing the bamboo. Split bamboo reinforcement ought to be moderately straight. Its breadth shouldn't exceed twenty to twenty five millimeter. whereas inserting, the basal and therefore the distal ends of the reinforcement should be alternated, to get a homogenous reinforcement space on the length of the member. The bamboo samples were treated with black Japan for water absorption. These bamboo strengthened columns were compared with axially strengthened steel concrete column that style for minimum reinforcement as per IS 456: 2000. These columns were tested beneath 100T capability UTM

Sr.No	Percentage	Shape	B	D	L	Cross Sec. Area	Peak Comp.	Displacement
	Bamboo		(mm)	(mm)	(mm)	(mm ²)	Load (kN)	(mm)
1	2.50%	Square	150	150	750	22500	153.5	4.95
2		Square	150	150	750	22500	192.9	5.53
3		Square	150	150	750	22500	181.2	7.45
4		Rectangular	150	230	750	34500	317	12
5		Rectangular	150	230	750	34500	309	7.63
6		Rectangular	150	230	750	34500	177	8
7		Circular	-	230	750	41547.7	329	12.11
8		Circular	-	230	750	41547.7	268	10.55
9		Circular	-	230	750	41547.7	216	14.21
10	3%	Square	150	150	750	22500	142.8	7.83
11		Square	150	150	750	22500	125	6.84
12		Square	150	150	750	22500	170	9.49
13		Rectangular	150	230	750	34500	239.4	12.5
14		Rectangular	150	230	750	34500	208	9.96
15		Rectangular	150	230	750	34500	280	5.57
16		Circular	-	230	750	41547.7	366	9.28

17		Circular	-	230	750	41547.7	155.8	13.23
18		Circular	-	230	750	41547.7	221	8.85
19	3.50%	Square	150	150	750	22500	196.5	7.18
20		Square	150	150	750	22500	180.5	6.19
21		Square	150	150	750	22500	136.2	10.98
22		Rectangle	150	230	750	34500	290	3.72
23		Rectangle	150	230	750	34500	205	7.32
24		Rectangle	150	230	750	34500	281	10.83
25		Circular	-	230	750	41547.7	360	6.91
26		Circular	-	230	750	41547.7	240	10.83
27		Circular	-	230	750	41547.7	245	7.2



Fig. 1- Compression test on circular bamboo reinforce concrete column



Fig. 2- Failure of rectangular bamboo reinforce concrete column.



Fig. 3- Failure of square bamboo reinforce concrete column

IV. CONCLUSION

Concrete members bolstered with sections of bamboo culms, that had been split on their horizontal axes, developed significantly higher load capacities than unreinforced concrete beams of comparable sections.

- Bamboo concrete slab: once recent concrete is poured, its water can moisten the bamboo; then, the concrete can harden and lose water in order that the bamboo can once more dry out. This drying process can utterly break any bond between the bamboo and also the concrete. It is often considered that underground wetness is high at any times thus provide of water to the concrete will be accomplished.
- The seminar report shows that bamboo can substitute steel satisfactorily. The structural parts developed and studied could also be utilised in many building constructions.

Bamboo reinforcement technique is used for every main and distribution reinforcement as a result of it absolutely was same earlier in deep hassle steel reinforcement. It's three times cheaper than steel reinforcement technique.

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