Utilization of Bamboo as Reinforcement in RCC Building And Assessment With Steel Reinforcement

Imran Siraj Khan[1], Nitesh K. Jibhkate[2]
[1]Dept of B.Arch
[2]Assistant Prof., Dept of B.Arch
[1, 2] Tulsiramji Gaikwad-Patil College of Architecture, Nagpur

Abstract- *Reinforced concrete is most common material in the world but it become expensive when as reinforcement steel is used. So this present paper deals with the utilization of bamboo as reinforcement in place of steel. Cost analysis and limitations of bamboo. The intention of research is to utilize bamboo as a key structural material, for a safe and durable house, which can be affordable by poor people*

The utilization of bamboo reinforcement as replacement of steel reinforcement is gaining immense importance today, mainly on account of the improvement in the economical aspect combined with ecological benefits. To study the effect of replacement of steel reinforcement by bamboo reinforcement, designs have been conducted on column size 230 mm X 300 mm. Also the effect of replacement of steel reinforcement by bamboo reinforcement, have been conducted on Beam & Slab.

Keywords- Bamboo, Flexural Strength, Cost Estimation, Economical Low cost housing,

I. INTRODUCTION

In recent times, the high cost and general shortage of reinforcing steel in many parts of the world has led to increasing interest in the possible use of alternative locally available materials for the reinforcement of concrete. This is the case especially in the developing countries where about 80% of the population live in villages.

There are many uses of Bamboo, the most common uses include:-culinary, medical, paper, instruments, and construction.

Bamboo has been used in construction for temporary uses such as scaffolding.

Industrially treated bamboo has shown suitability for use within a composite and has already been successfully utilized for structural and non-structural applications in construction.

Bamboo is a low-cost and low-energy substitute construction material. And one of the fastest growing plants has got a great economic potential.

Bamboo has been used in constructions of bridges and houses for Thousands of years in Asia. Bamboo takes less energy to harvest and transport.

II. OBJECTIVES

- To study the building typology.
- To study the Mechanical property of bamboo and Steel.
- To study the strength of bamboo and steel.
- Comparative study between Mechanical property steel and bamboo.
- To compare the quantity required of Bamboo & steel for Compression member (column) in building.
- To compare the quantity required of Bamboo & steel for Tension members (beam & slab) in building.
- Compare the rate of Bamboo & steel as reinforcement in Building.
- To study the estimate of building if bamboo used as a reinforcement. And comparison with steel reinforcement

III. PHYSICAL PARAMETERS

1. Mechanical property of bamboo

Table No. 1. Mechanical property of bamboo

Mechanical property of bamboo	Value
ultimate compressive strength	55.0 Mpa
allowable compressive stress	27.6 Mpa
ultimate tensile strength	124.1 Mpa
allowable tensile stress	27.6 Mpa
allowable bond stress	344.0 Kpa
modulus of elasticity	17.2 Gpa

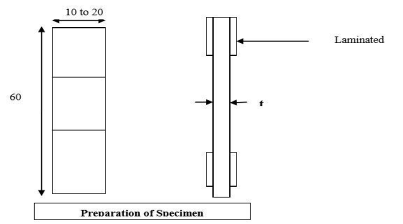
2. Mechanical property of steel

Table No. 2. Mechanical property of steel

Mechanical property of steel	Value
Yield point	332 MPa
Ultimate tensile strength	673 MPa
Modulus of Elasticity	165 GPa
Strength at Break	586 MPa
Elongation at Break	35 MM

Tensile test of bamboo *(as per is 6874:2008)*

Table No. 3. Tensile test of bamboo



3.2.2. Calculations

The maximum tensile strength σ_{ult} N/mm², shall be determined as follows:

$$\sigma_{ult}=\frac{F_{ult}}{A}$$

Where

F_{ult} = maximum load, in N; and
A= area of cross-section of test specimen, in mm².
σ_{ult}, shall be rounded to the nearest full number.

3.2.3. Result

Table 3- Tensile Test Result	
Culm Diameter (mm)	Tensile Stress (Mpa)
57.5	130.1

Tensile test of RCC

Table No. 4. Tensile test of RCC

Table 6.3 Split tensile strength test on cylinders

S.No	Mix identity	Ultimate load (kN)	Average ultimate loads (kN)	Split tensile strength at 28 days (N/mm^2)	Percentage increase in strength
		250			
1.	CC	240	236.66	3.35	---
		220			
		290			
2.	S10	270	280	3.96	18.20
		280			
		240			
3.	S20	330	283.33	4.01	19.71
		280			
		300			
4.	S30	280	286.67	4.05	22.72
		280			
		270			
5.	S40	280	296.6	4.19	25.07
		340			
		290			
6.	S50	270	280	3.96	18.20
		280			
		280			
7.	S60	280	283.33	4.00	16.72
		290			

Compression test of bamboo

Table No. 5. Compression test of bamboo

3.3.2. Calculation

The maximum compressive strength σ_{ult} ,in N/mm², shall be determined as follows:

$$\sigma_{ult}=\frac{F_{ult}}{A}$$

Where,

F_{ult} = maximum load, in N; and
A= area of cross-section of test specimen,

$=\frac{\pi}{4}[D^2-(D-2t)^2]$, in mm².

D=outer diameter, in mm; and
t=wall thickness, in mm.

σ_{ult}, shall be rounded to the nearest 0.5N/mm².

3.3.3. Result

Table 4- Compressive Test Results	
Sample	Compressive Stress (Mpa)
Nodes	70.1
Without Nodes	76.56

Compression test of RCC

Table No. 6. Compression test of RCC

Table 6.2 Compressive strength test on concrete specimens

S.No	Mix Identity	Ultimate load kN		Average ultimate load kN		Comp.strength N/mm^2		% increase in strength at 28 days
		7 Days	28 Days	7 Days	28 Days	7 Days	28 Days	
		460	770			20.15		
1.	CC	480	720	453.33	745		33.11	---
		500	750					
		580	850			21.33		
2.	S10	600	880	480	876.66		38.96	17.67
		560	900					
		620	960			5.78		
3.	S20	630	970	580	970.00		43.11	30.20
		650	980					
		680	980					
4.	S30	650	1000	633.33	1006.67	27.15	44.77	35.00
		675	1040					
		560	1160					
5.	S40	540	950	668.33	1055.00	29.70	46.8	41.34
		520	1055					
		480	940					
6.	S50	465	860	540.00	893.33	24.00	39.70	19.99
		490	880					
		460	880					
7.	S60	480	840	478.33	860	21.26	38.22	15.43
		500	860					

IV. PREPARATION OF BAMBOO

1. sizing

When using bamboo as reinforcement, splints are **preferable** over whole culms. This is due to the size of whole culms and also considering culms are hollow, therefore possessing a higher buckling failure, which could be possible after load is applied to the concrete, or even due to the self-weight of the concrete.

2. Seasoning

After Bamboo is cut, it needs to be dried, seasoned and leached prior to use. This seasoning process will last two to four weeks, and culms must have regularly spaced support to minimize warping. Leaching is the removal of sap after harvest, and is done via post-harvest photosynthesis or with force from mechanical treatments. These practices include pumping water through freshly cut culms, forcing sap out immersing culms in running steam and placing the base of the culms in water which will leach out the sap and also allow for full consumption of sugars by the bamboo. Bamboo should be dried slowly and evenly, in the shade. This will avoid the cracking of external skin membrane, and therefore reduce opportunities for fungal and pest infestations.

3. Bending

Bamboo can be permanently bent and shaped if heat and pressure is applied. This technique can be used to form the bamboo into ties, stirrups, and to put hooks or pegs into the bamboo for additional anchorage in the concrete.

4. **Water Proof Coatings**

Bamboo has a high water absorption capacity, and with this added water comes a decrease in mechanical strength due to excess hydrogen bonding between water molecules and the cellulose fiber of the bamboo. A water proof coating then becomes apparent and essential, if bamboo is to be used as a structural material. There are many water replant coatings which can be considered, such as coal tar, bituminous paint, sodium silicate, epoxy, the list goes on.

A water resistant treatment will need to be applied to the bamboo before applying it as reinforcement to concrete. In all cases of treatment applications, only a thin coating shall be applied.

V. USE OF BAMBOO WITH MORTAR AND CONCRETE

During studies conducted by Mazuzetal, (2011) to suggests that compression test of bamboo gives an average stress of 41.02 Mpa

Which is quite sufficient for a low cost building, because load of low cost buildings are not so high? And such bamboo can be safely used as the feasible alternative of concrete column.
The study also suggests that lower stress ratio composite bamboo members provide better strength.

Que.1 Calculation of load take by a column 230 mm X 300 mm and height of column is 3m with respect to concrete with steel and concrete with bamboo.
Column size = 230 MM X 300 MM
Room size = 3 M X 3 M
Area of room = 9 SQ. M

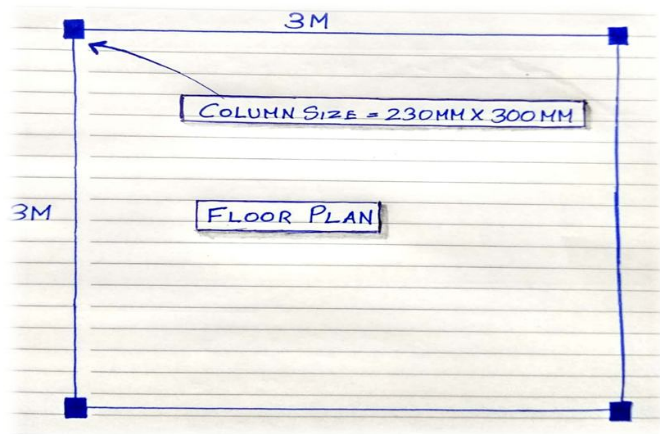


Fig. 1 showing plan of a room with 4 columns

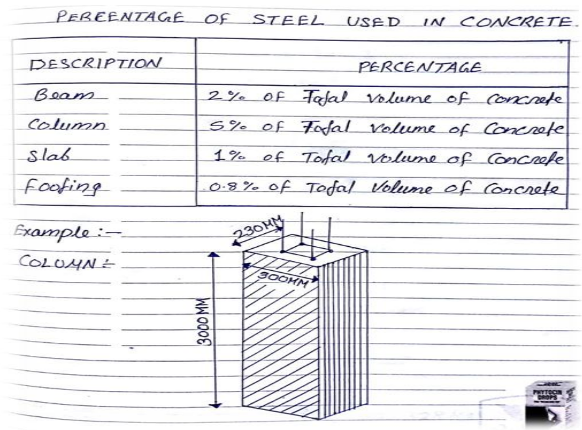
Concrete and Steel

Self weight of concrete = 2500 kg/m = 250 KN
Self weight of steel = 7850 kg/m = 785 KN
Self weight of column = 250 + 785 = 1035 K N
Factor of safety = 1035 x 1.5 = 1552 KN
Room has 4 column = 4 x 1552 = 6208 KN
Let's assume that 4 column are taking = 1000 KN

Concrete and Bamboo

Self weight of concrete = 2500 kg/m = 250 KN
Self weight of bamboo = 400 kg/m = 40 KN
Self weight of column = 250 + 40 = 290 K N
Factor of safety = 290 x 1.5 = 435 KN
Room has 4 column = 4 x 435 = 1740 KN

Let's assume that 4 column are taking = 1000 KN


PERCENTAGE OF STEEL USED IN CONCRETE.

DESCRIPTION	PERCENTAGE
Beam	2% of Total volume of concrete
Column	5% of Total volume of Concrete
Slab	1% of Total volume of Concrete
Footing	0.8% of Total Volume of Concrete

Fig. 2 Percentage of steel use in column

Market survey on bamboo for price and size
Product description

Diameter = 19.05 mm, 25.40 mm
Size = 5.5 – 7.3 m
Price = 55 – 80 Rs.

Fig. 3 Diameter of bamboo

CALCULATION FOR SLAB

Design a simple supported slab panel for a hall of clear dimension of 3m x 8m.Supported on 230 mm thick wall all around the slab. Slab carries a super imposed load of 2.5 kN/m^2 with floor finish of 0.5 kN/m^2. Use M_{20} grade of concrete and Fe 415 grade of steel.

Concrete and Steel

Solution:-

Step1:- ly/ lx = 8/3 =2.67>2 (One way Slab)
Step2:- l/d = 20 x M.F
d = 3230/ 20 x 1.5
d = 107.67 ~110 mm
Assuming 15mm clear cover and 10mm diameter bar
D = 10mm ϕ bar
D = d + 15 + ϕ/ 2
D = 110 + 15 + 5 = 130 mm = 0.13 m
Step3:- Dead Load
D.L = b. D. V
= 1 x 0.13 x 25
= 3.25 kN/m
Live Load = 2.5 x 1
= 2.5 kN/m
Floor Finish = 0.5 x 1
= 0.5 kN/m
Total Load (W) = Dead load + Live load + Floor Finish
= 3.25 + 2.5 + 0.5
= 6.25 kN/m
Ultimate Load Wu = 6.25 x 1.5
= 9.375 kN/m
Step4:- Effective Span
Leff = C.S + Ws = 3 + 0.23 = 3.23 m
OR = C.S + d = 3 + 0.110 = 3.110 m
Leff = 3.110 m
Step5:- Maximum Bending Movement
Mx = Wu x Leff/8
= 11.33 kN.m
= 11.33 x 10^6 N.mm
Step6:- Check for Depth
Mu = Mu lim.
11.33 x 10^6 = 0.138 x fck x b x d2 ---- For 415
11.33 x 10^6 = 0.138 x 20 x 1000 x d2
d = 64.07 mm < d = 110 mm
Hence safe
Step7:- Area of Main Steel
Ast=(0.5Fck/Fy) x(1-sqrt(1-((4.6Mu)/Fck.bd^2)) xbd
Fck=grade of cement i.e M25, M20
Fy=grade of steel i.e.Fe415,Fe250
Mu= moment b= width d= depth
Ast = ((0.5 x 20) / 415) x [1- sqrt (1- ((4.6 x 11.33 x $10^{6)}$/ 20 x 1000 x (110)2)] x 1000 x 110
Ast = 302 mm^2
Step8:- Spacing
= (1000 x π/4 x 102)/302
= 260 mm
Step9:- Area of Steel Diameter
According to page number 45 of IS code
415 and 500 has Ast. Min = 0.12% b x D
250 has Ast. Min = 0.15% b x D
Ast. Min = 0.12/100 x 1000 x 130
= 156 mm^2
Ast > Ast. Min
Provide 8mm ϕ bars Fe250 grade.
Ast. Distribution = Ast min-----------for Fe250

= 0.15 / 100 x 1000 x 130

Ast. Distribution = 195 mm^2

Spacing distribution = (1000 x π/4 x 82) / 195

= 257.77 mm ~255 mm

Concrete and Bamboo

Solution:-

Step1:- ly/ lx = 8/3 =2.67>2 (One way Slab)

Step2:- l/d = 20 x M.F

d = 3230/ 20 x 1.5

d = 107.67 ~110 mm

Assuming size of bamboo 20mm ϕ and 15 mm clear cover.

D = 10 mm ϕ bar

D = d + 15 + ϕ/ 2

D = 110 + 15 + 10 = 135 mm

~140 mm = 0.14 m

Step3:- Dead Load

D.L = b. D. V

= 1 x 0.14 x 25

= 3.5 kN/m

Live Load

= 2.5 x 1 = 2.5 kN/m

Floor Finish

= 0.5 x 1

= 0.5 kN/m

Total Load (W) = Dead load + Live load + Floor Finish

= 3.25 + 2.5 + 0.5 = 6.5 kN/m

Ultimate Load Wu = 6.5 x 1.5

= 9.75 kN/m

Step4:- Effective Span

Leff = C.S + Ws = 3 + 0.23 = 3.23 m

OR = C.S + d = 3 + 0.110 = 3.110 m

Leff = 3.110 m

Step5:- Maximum Bending Movement

Mx = Wu x Leff/8

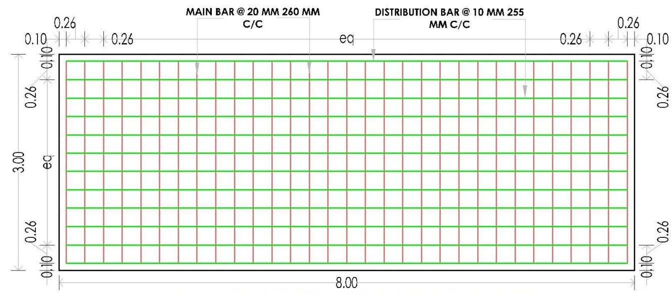
= 11.78 kN/m

= 11.78 x 106 N.mm

Step6:- Area of Main Bamboo

Area of bamboo = (0.5 x 20) / 125 x [1- sqrt 1- ((4.6 x 11.33 x $10^{6)}$/ 20 x 1000 x $(110)^2$)] x 1000 x 110

Area of bamboo = 1047 mm2



SLAB DEATAIL WITH STEEL RENIFORCEMENT

Step7:- Spacing

= (1000 x π/4 x 202)/1047.6

= 299.88 mm = 300 mm

Step8:- Area of Bamboo Diameter

Provide 12.7 mm ϕ bamboo for distribution. Assuming 0.15% Distribution Bamboo of total concrete surface area.

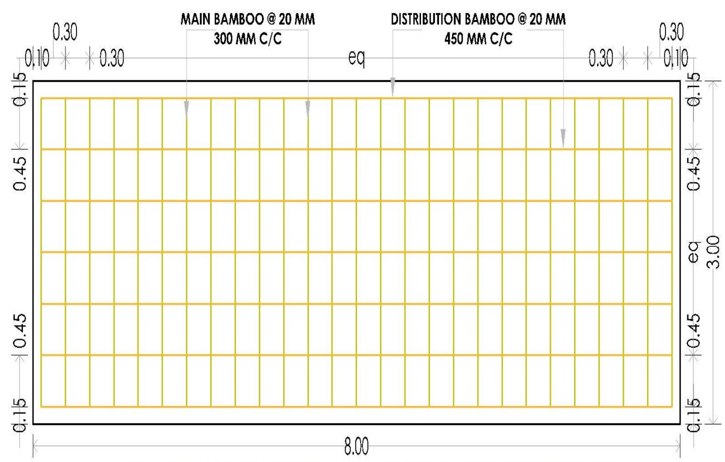
Area of Distribution bamboo = 0.2 / 100 x 1000 x 140

Area of Distribution bamboo = 280 mm^2

Step9:- Spacing

Spacing distribution = (1000 x π/4 x 12.72) / 280

= 452 mm ~450 mm C/C



SLAB DEATAIL WITH BAMBOO RENIFORCEMENT

CALCULATION FOR BEAM

Design a simply supported RCC beam for a span of 4.2 M. The beam is subjected to superimposed load of 20 KN/M. Use M_{20} Grade of concrete and Fe415 Grade of steel.

Calculation of Concrete and Steel

Solution: - Given Fck = 20 N/ mm^2

Fy = 20 N/ mm^2

f.f = 0.5 N/ mm^2

Step1:- Trial Depth = L/ 10 = 4200/10 = 420 mm

Step2:- Load Calculation

Dead load = D x b x ɣ = 0.42 x 0.23 x 25 = 2.41 kN/m

Live load = 20 kN/m

Total load (w) = Dead load + Live load

= 2.41 + 20 = 22.41 kN/m

Step3:- Ultimate load (Wu)

Wu = W x factor of safety = 22.41 x 1.5 = 33.61 kN/m

Step4:- Maximum Bending Movement (Mu)

$Mu = Wu \times L^2/8 = 33.6 \times (4.2)^2/8 = 74.11$ Kn.m

$Mu = 74.11 \times 10^6$ N-mm

Step5:- Check for Depth

Mu = Mu limit

$74.11 \times 10^6 = 0.138 \times 20 \times 230 \times d^2$

d = 341.68 mm

Assume 40 mm cover

d = D -40 = 420 – 40

= 380

341 < 380 hence it is Safe

Step6:- Design of Steel

Area of Steel = (0.5 x 20) / 415 x [1- sqrt1-((4.6 x 74.11×10^6)/ 20 x 230 x $(380)^2$)] x 230 x 380

Area of Steel = 637 mm^2

Step7:- Check for Minimum & Maximum Steel

Ast. Mim/ bxd = 0.85 / fy

Ast. mim = 179.01 mm^2

Ast. max = 4 % Ag

Ag = Gross area of beam

= 230 mm x 420 mm

Ast. max = 3864 mm^2

Ast. mim < Ast. < Ast. Max

179.01 < 637 < 3864

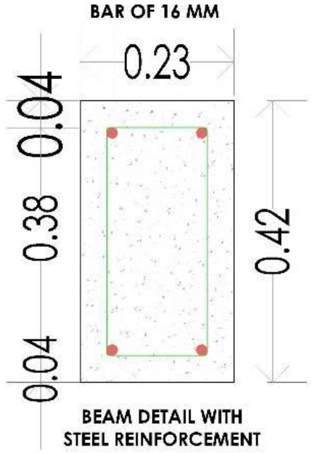
4 no. of bars

$4 \times \pi/4 \times \phi^2$ = Ast.

$\phi^2 = 637 / \pi = 14.23$

= 16mm bars

4 NO. MAIN STEEL BAR OF 16 MM



BEAM DETAIL WITH STEEL REINFORCEMENT

Calculation of Concrete and Bamboo

Solution: - Given Fck= 20 N/ mm^2

Fy = 20 N/ mm^2

f.f = 0.5 N/ mm^2

Step1:- Trial Depth = L/ 10 = 4200/10 = 420 mm

Step2:- Load Calculation

Dead load = D x b x γ = 0.42 x 0.23 x 25 = 2.41 kN/m

Live load = 20 kN/m

Total load (w) = Dead load + Live load

= 2.41 + 20 = 22.41 kN/m

Step3:- Ultimate load (Wu)

Wu = W x factor of safety = 22.41 x 1.5 = 33.61 kN/m

Step4:- Maximum Bending Movement (Mu)

$Mu = Wu \times L^2/8 = 33.6 \times (4.2)^2/8$ = 74.11 kN/m

$Mu = 74.11 \times 10^6$ N-mm

Step6:- Design of Bamboo

Area of Steel = (0.5 x 20) / 125 x [1- sqrt1- ((4.6 x 74.11×10^6)/ 20 x 230 x $(380)^2$)] x 230 x 380

Area of Steel = 2113.7 mm^2

Step7:- Check for Minimum & Maximum Steel

Ab. Mim/ bxd = 0.85 / fy

Ab. mim = 179.01 mm^2

Ab. max = 4 % Ag

Where Ab = Area of Bamboo

Ag = Gross area of beam

= 230 mm x 420 mm

Ab. max = 3864 mm^2

Ab. mim < Ab. < Ab. Max

179.01 < 2113.7 < 3864

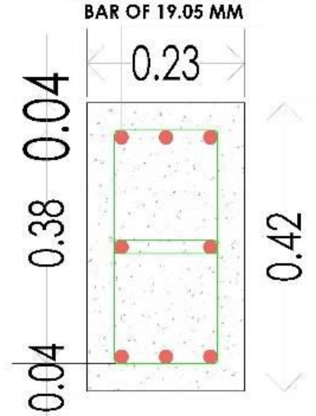
Step8:- Find number of Bamboo in Beam

No. of bars x $\pi/4 \times \phi^2$ = Ab

No. of bars = (2113.7 x 4) / $(19.05)^2 \times \pi$

No. of bars = 7.45 = 8

8 NO. MAIN BAMBOO BAR OF 19.05 MM



BEAM DETAIL WITH BAMBOO REINFORCEMENT

Cost Calculation of Column Keeping Load Constant (1000 kN)

Table No. 7. Calculation for the steel use in column

1 m steel rod 12mm	47 Rs.
one rod	3 M
4 rods	3 x 4 = 12M
cost of one column	12 x 47 = 564 Rs.
4 columns	4 x 564 = 2256 Rs.

Table No. 8. Calculation for the bamboo use in column

7.3 M bamboo	55 - 80 Rs.
We need 2 bamboo	7.3 x 2 = 14.6 M
4 rods of bamboo 12 M	160 Rs.
Cost of one column	160 Rs.
4 columns	4 x 160 = 640 Rs.

Fig. 4 showing steel column sizes

Fig. 5 showing size variation in bamboo column

Steel Reinforcement Nominal Dimensions - Round Sections

Table No. 9. Showing diameter and sectional area of steel

Sr. No.	Nominal Diameter (mm)	Cross Sectional. Area (sq. mm)
1	10	78.54
2	12	113.1
3	14	153.94
4	16	201.06
5	18	254.47
6	20	314.16
7	22	380.13
8	25	490.87
9	28	615.75
10	32	804.25

Bamboo Whole Culms Dimension and Diameter

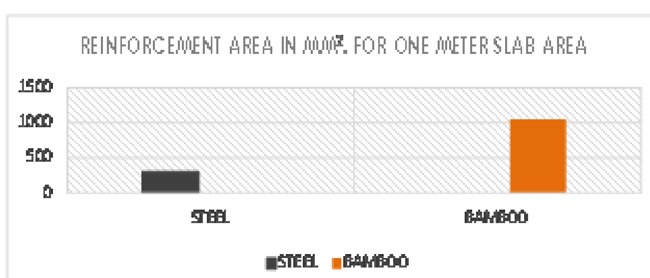
Table No.10 Showing diameter and sectional area of bamboo

Sr. No.	Diameter (mm)	Area (sq. mm)
1	9.39	68.81
2	12.7	126.68
3	15.74	194.58
4	19.05	284.72
5	25.4	506.71
6	50.8	2026.83

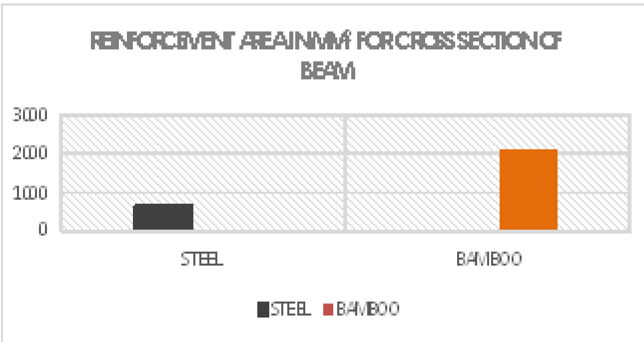
VI. RESULT OF ANALYSIS

Cost Comparison of Steel Reinforcement & Bamboo Reinforcement

ESTIMATE OF SLAB REINFORCEMENT				
SR. NO	DISCRIPTION	LENGTH & WIDTH	AREA IN M.SQ	COST
SLAB				
1	STEEL 20MM ϕ	31 X 2.7	86.80	□6,076.00
	STEEL 10MM ϕ	12 X 7.8	93.60	□4,399.20
TOTAL			180.40	□10,475.20
2	BAMBOO 20MM ϕ	27 X 2.7	72.90	□801.90
		7 X 7.8	54.60	□600.60
TOTAL			127.50	□1,402.50



ESTIMATE OF BEAM REINFORCEMENT				
SR. NO	DISCRIPTION	LENGTH & WIDTH	AREA IN M.SQ	COST
BEAM				
1	STEEL 16MM Φ	8 X 8	64.00	□3,520.00
		12 X 3	36.00	□1,980.00
TOTAL			100.00	□5,500.00
2	BAMBOO 19.05 MM Φ	16 X 8	128.00	□1,408.00
		24 X 3	72.00	□792.00
TOTAL			200.00	□2,200.00



VII. CONCLUSION

- After the analysis it is concluded that the bamboo & steel has different mechanical properties. Steel has more tensile strength as compare to bamboo.
- Bamboo can be used as a construction material in replacement of reinforcement bars. it has required mechanical properties required for building material.
- Bamboo has very good tensile strength, but according to the availability of shape and size of bamboo we can use it up to two storey building.
- It is necessary to treat bamboo before it use in construction.
- Bamboo can be used as reinforcement in compression member (column)in buildings up to two storey.
- It is concluded that after calculation of cost required for the same no. of column steel reinforcement is Four times costlier than bamboo reinforcement.
- It is also concluded that from observation of results the cost of steel reinforcement in Tension member (Slab & Beam) is much more as compare to bamboo reinforcement.
- Finally it is concluded that utilization of bamboo as reinforcement in RCC building is a good for low cost economical structure. But due to some limitation it is restricted to two storey building.

REFERENCES

[1] International Journal of Advance Engineering and Research Development (IJAERD) Volume 4, Issue 7, July-2017, e-ISSN: 2348 - 4470, print-ISSN: 2348-6406

[2] IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 1 (Jul. - Aug. 2013), PP 50-61 www.iosrjournals.org

[3] H. E. Glenn. "Bamboo reinforcement in Portland cement concrete," Engineering Experiment Station, Clemson

[4] Agricultural College, Clemson, South Carolina, Bulletin No. 4, May 1950.

[5] U. S. Army Engineer Waterways Experiment Station. Technical Report No. 6-646: "Precast concrete elements with

[6] “Bamboo reinforcement" by E. F. Smith and K. L. Saucier. Vicksburg, Mississippi, May 1964.

[7] S. R. Mehra and R. G. Ghosh. "Bamboo-reinforced soil-cement," Civil Engineering and Public Works Review, Vol.

[8] 60, no. 711, October 1965; vol. 60, no. 712. November 1965.

[9] "Concrete floors on ground," Portland Cement Association Concrete Information, ST-51.

[10] American Concrete Institute. "Building code requirements for reinforced concrete," (ACI 318-56). May 1956.

[11] Department of the Navy, Bureau of Yards and Docks. Design Manual NAVDOCKS DM-2, Structural Engineering. October 1964.

[12] National Building Code of India (2004) Bureau of Indian Standards, New Delhi.

[13] Nugroho, N. and Bahtiar, E.T. (2013) Bamboo Taper Effect on Third Point Loading Bending Test. International Journal of Engineering and Technology,5(3)

[14] Indian Standard Code PLAIN AND REINFORCED CONCRETE - CODE OF PRACTICE (Fourth Revision) (IS. 456 : 2000)

[15] Textbook By Devdas Menon, S. Unnikrishna Pillai - “Reinforced Concrete Design” - Third Edition