

*The GRIHA Summit 2015 March 12<sup>th</sup>, 13<sup>th</sup> & 14<sup>th</sup> at  
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**Reinforced Bamboo Concrete Constructions**

*by*

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**BAMBOO HAS HIGH STRENGTH TO WEIGHT RATIO  
AND EASE IN WORKING WITH SIMPLE TOOLS. 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, SPECIALLY, FOR HOUSING IN RURAL AREAS.**

**HOWEVER, ENOUGH ATTENTION HAS NOT BEEN PAID TOWARDS RESEARCH AND DEVELOPMENT IN BAMBOO AS CONSTRUCTION MATERIAL FOR DIFFERENT USES.**

**LIGHTNESS MAKES BAMBOO SUITABLE FOR HOUSING IN DISASTER- PRONE AREAS LIKE PRONE TO EARTHQUAKE. IT HAS THE CAPACITY TO ABSORB MORE ENERGY AND SHOW LARGER DEFLECTIONS BEFORE COLLAPSE AND AS SUCH IS SAFER UNDER EARTH QUAKE TREMORS.**

**AT PRESENT, THE APPLICATION OF BAMBOO AS AN ENGINEERING MATERIAL IS LARGELY BASED ON PRACTICAL AND ENGINEERING EXPERIENCE SINCE THE DESIGN GUIDELINES ARE INADEQUATE.**

**IN A CIRCULAR CROSS- SECTION, BAMBOO IS GENERALLY HOLLOW AND FOR STRUCTURAL PURPOSES THIS FORM IS QUITE EFFECTIVE AND ADVANTAGEOUS. THE STRENGTH OF BAMBOO CULMS, THEIR STRAIGHTNESS, LIGHTNESS COMBINED WITH HARDNESS, RANGE AND SIZE OF HOLLOWNESS MAKE THEM POTENTIALLY SUITABLE FOR A VARIETY OF APPLICATIONS BOTH STRUCTURAL AND NON-STRUCTURAL.**

WITH GOOD PHYSICAL AND MECHANICAL PROPERTIES, LOW SHRINKAGE AND GOOD AVERAGE DENSITY, BAMBOO IS WELL SUITED TO REPLACE BOTH STRUCTURAL STEEL AND REINFORCING STEEL.

### *SPECIES OF BAMBOO*

MORE THAN 100 SPECIES OF BAMBOO ARE AVAILABLE IN INDIA AND A FEW OF THEM ARE SOLID BUT MOST OF THEM ARE HOLLOW IN STRUCTURE.

## MOISTURE CONTENT IN BAMBOO

WITH DECREASE OF MOISTURE CONTENT (M) THE STRENGTH OF BAMBOO INCREASES EXPONENTIALLY AND BAMBOO HAS AN INTERSECTION POINT (FIBRE SATURATION POINT) AT AROUND 25 PERCENT MOISTURE CONTENT DEPENDING UPON THE SPECIES.

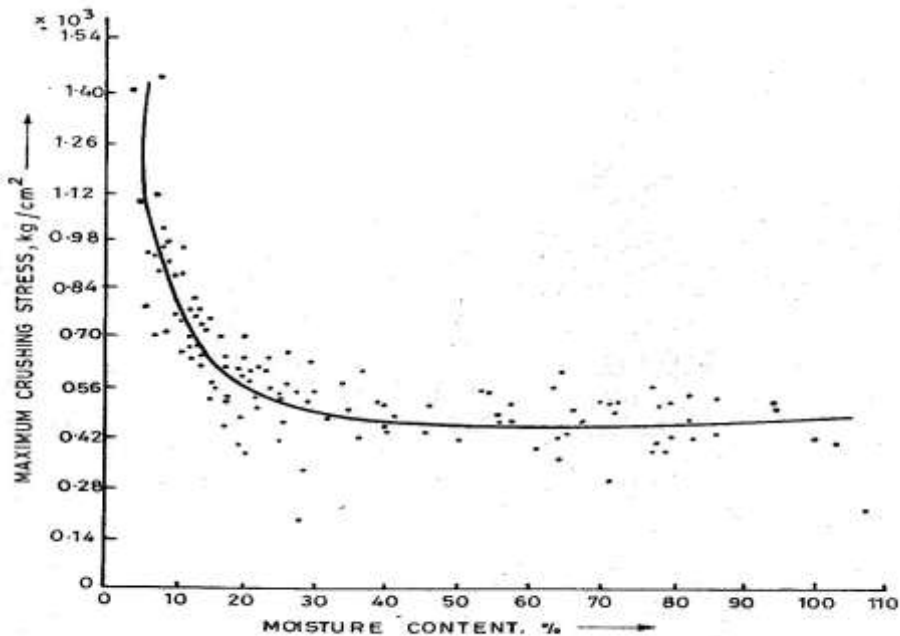


FIG. 1 MOISTURE STRENGTH RELATIONSHIP BAMBUSA NUTANS (BAMBOO)

**AIR SEASONING OF SPLIT OR HALF-ROUND BAMBOO DOES NOT POSE MUCH PROBLEM BUT CARE HAS TO BE TAKEN TO PREVENT FUNGAL DISCOLOURATION AND DECAY. HOWEVER, RAPID DRYING IN OPEN SUN CAN CONTROL DECAY DUE TO FUNGAL AND INSECT ATTACK.**

**NOTE:-**

**A GENERAL OBSERVATION HAS BEEN THAT IMMATURE BAMBOO GETS INVARIABLY DEFORMED IN CROSS-SECTION DURING SEASONING AND THICK WALLED IMMATURE BAMBOO GENERALLY COLLAPSES.**

Table 1 Physical and Mechanical Properties of Indian Bamboos (in Round Form)  
(Clauses 4.1 and 5.1.2)

Sl No.	Species	Properties						
		In Green Condition				In Air-Dry Condition		
		Density kg/m <sup>3</sup> (1)	Modulus of Rigidity N/mm <sup>2</sup> (2)	Modulus of Elasticity 10 <sup>3</sup> N/mm <sup>2</sup> (3)	Maximum Compressive Strength N/mm <sup>2</sup> (4)	Density kg/m <sup>3</sup> (5)	Modulus of Rigidity N/mm <sup>2</sup> (6)	Modulus of Elasticity 10 <sup>3</sup> N/mm <sup>2</sup> (7)
i)	<i>Bambusa nardulata</i>	594	85.1	13.61	36.7	678	88.1	21.41
ii)	<i>B. dolosa</i>	780	65.4	7.31	46.7	—	—	—
iii)	<i>B. bambusa</i> (Syn. <i>B. arundinacea</i> )	534	56.5	5.85	25.3	460	84.1	8.95
iv)	<i>B. burmanica</i>	578	59.7	11.01	28.9	672	105.0	17.61
v)	<i>B. glaucescens</i> (Syn. <i>B. nana</i> )	666	82.8	14.77	33.9	—	—	—
vi)	<i>B. nana</i>	660	72.9	6.82	43.6	675	92.4	18.72
vii)	<i>B. pallida</i>	725	55.2	12.90	34.8	—	—	—
viii)	<i>B. petasoptera</i>	614	28.3	3.12	52.1	659	35.5	4.40
ix)	<i>B. nuda</i>	658	51.1	5.98	46.7	722	66.7	19.67
x)	<i>B. stricta</i>	628	34.1	3.38	38.1	—	—	—
xi)	<i>B. vulgaris</i>	626	41.5	2.47	38.8	—	—	—
xii)	<i>Cephalostachyum pergracile</i>	665	52.6	11.36	36.7	640	71.3	18.22
xiii)	<i>Dendrocalamus strictus</i>	597	17.2	0.41	25.2	—	—	—
xiv)	<i>D. bambusa</i>	513	40.0	2.49	43.4	—	—	—
xv)	<i>D. longispatus</i>	715	33.1	3.21	42.1	644	47.8	6.05
xvi)	<i>D. monostachyus</i>	525	26.5	2.44	48.5	644	37.8	3.77
xvii)	<i>D. strictus</i>	625	25.4	11.88	55.9	728	119.1	15.90
xviii)	<i>Melocanna baccifera</i>	617	33.2	11.39	53.8	791	57.6	12.95
xix)	<i>Oxytenanthera abyssinica</i>	628	83.6	14.96	48.8	—	—	—
xx)	<i>Thyrsostachys oliveri</i>	733	61.9	8.72	48.8	758	80.0	12.15

## NOTES:

1. As the strength of split bamboo is more than that of round bamboo, the results of tests on round bamboo can be safely used for designing with split bamboo.

2. The values of stress in N/mm<sup>2</sup> have been obtained by converting the values in kg/cm<sup>2</sup> by dividing the same by 9.8.

Table 2 Safe Working Stresses of Bamboos for Structural Designing<sup>1)</sup>  
(Clauses 4.1.1, 4.2, 5.3 and 5.4)

Sl No.	Species	Extreme Fibre Stress in Bending N/mm <sup>2</sup> (3)	Modulus of Elasticity 10 <sup>3</sup> N/mm <sup>2</sup> (4)	Allowable Compressive Stress N/mm <sup>2</sup> (5)
(1)	(2)	(3)	(4)	(5)
<b>GROUP A</b>				
i)	<i>Bambusa glaucescens</i> (Syn. <i>B. nana</i> )	20.7	3.28	15.4
ii)	<i>Dendrocalamus strictus</i>	18.4	2.66	10.3
iii)	<i>Oxytenanthera abyssinica</i>	20.9	3.31	13.3
<b>GROUP B</b>				
iv)	<i>Bambusa balcooa</i>	16.4	1.62	13.3
v)	<i>B. pallida</i>	13.8	2.87	15.4
vi)	<i>B. nana</i>	13.2	1.47	13.0
vii)	<i>B. nuda</i>	12.8	1.77	11.6
viii)	<i>B. auriculata</i>	16.3	3.34	10.5
ix)	<i>B. burmanica</i>	14.9	2.45	11.4
x)	<i>Cephalostachyum pergracile</i>	13.2	2.48	10.5
xi)	<i>Melocanna baccifera</i> (Syn. <i>M. bambusaoides</i> )	13.3	2.53	15.4
xii)	<i>Thyrsostachys oliveri</i>	15.5	2.16	13.4
<b>GROUP C</b>				
xiii)	<i>Bambusa arundinacea</i> (Syn. <i>B. bambusa</i> )	14.6	1.32	10.1
xiv)	<i>B. ventricosa</i>	8.5	0.75	10.3
xv)	<i>B. vulgaris</i>	10.4	0.64	11.0
xvi)	<i>Dendrocalamus longispatus</i>	8.3	1.22	12.0

NOTE — The values of stress in N/mm<sup>2</sup> have been obtained by converting the values in kg/cm<sup>2</sup> by dividing the same by 10.

<sup>1)</sup> The values given pertain to testing of bamboo in green condition.

SO FAR BAMBOO HAS MAINLY BEEN USED FOR TRUSSES OR LIGHT WEIGHT SINGLE STOREY SLOPED ROOF HOUSES USING BAMBOO AS SUPPORTING COLUMNS AND ROOF BEAMS ETC. BUT RECENTLY IT HAS NOW BEING USED AS REINFORCING MATERIAL IN CONCRETE REPLACING STEEL REINFORCEMENTS

*JAIN TEMPLE AT CHENNAI*  
*USING BAMBOO IN PLACE OF STEEL*



**IN THE PROJECT OF JAIN TEMPLE, THE USE OF REINFORCING STEEL WAS NOT ALLOWED FROM RELIGIOUS CONSIDERATIONS. SO BAMBOO WAS USED IN PILE, PILE CAP, COLUMNS & BEAMS.**

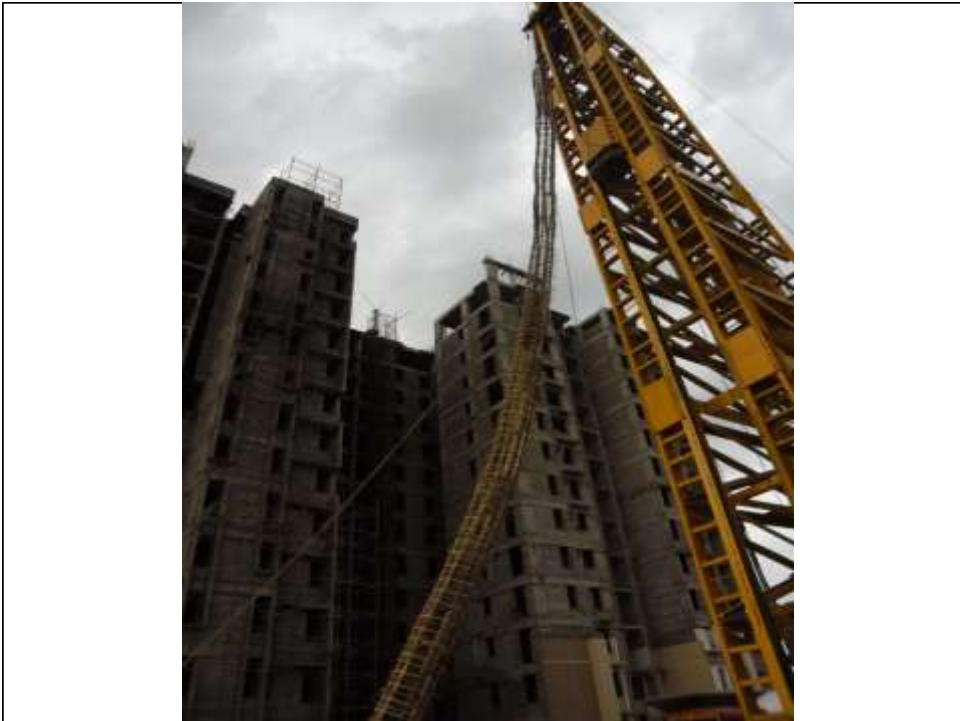


















































**THUS BAMBOO CAN BE EFFECTIVELY USED AS REPLACEMENT OF REINFORCING STEEL TO SAVE ENERGY. MORE WORK IS REQUIRED TO BE CARRIED OUT IN THIS FIELD.**

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**THANK YOU**

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