

## **Bamboo: Cost Effective and Sustainable Building Material**

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**Abstract**—Bamboo is green construction material which is easily available, light in weight. Traditional building materials like cement and steel leads to continuous CO<sub>2</sub> emission which forced engineers to think for other greener construction material. Most of the population is unable to have their own houses due to increasing housing cost. Bamboo possesses satisfactory characteristic properties as sustainable material compared to steel and concrete. Flexibility property of bamboo makes it earthquake resistant. This paper shows suitability of bamboo as cost effective, sustainable green building material.

**Keywords**—Bamboo; sustainability; CO<sub>2</sub> emission; cost effective; earthquake resistant

### I. INTRODUCTION

Drastic climatic changes are primarily due to increase in amount of CO<sub>2</sub> percentage. Steel and concrete industries are main sources for tremendous CO<sub>2</sub> emission. About 11% of total CO<sub>2</sub> emission is due to steel industry while cement industry contributes about 9% to it. In case of bamboo, situation is vice versa it consumes CO<sub>2</sub> from environment and releases O<sub>2</sub>.

During earthquake, bamboo can withstand high degree of deformation as it possesses good elasticity. Therefore, bamboo houses when properly constructed are ductile.

In India, bamboo is available in ample quantity. Use of bamboo in construction lowers the project cost.

### II. LABORATORY TESTS

#### A. Compression Test:

Five treated Bamboo samples of length 180mm having node are tested under CTM machine. In these samples, four samples are individually tested and fifth sample has nut and bolt joint.

TABLE I  
COMPRESSION TEST RESULTS

SAMPLE NO.	CROSS SECTIONAL AREA (MM <sup>2</sup> )	FAILURE LOAD (KN)	FAILURE STRESS (N/MM <sup>2</sup> )
1	2106.00	28	13.29
2	1638.26	36	21.97
3	1482.76	29.9	20.16
4	1152.86	31	26.88
5	1185.05	50	21.17

Average Compressive Strength is found out to be 20.69 N/mm<sup>2</sup>.



Fig.1 Compression Test Samples

*B. Tension Test*

For this test bamboo of length 750mm is split vertically into 4 parts and test is performed on UTM. The grips of testing machine shall ensure that the load is applied along the longitudinal axis of the test piece and prevent longitudinal twisting.



*Fig 2 Tension Test Sample 1 While Testing In UTM Machine*

TABLE II

TENSION TEST RESULT OF SAMPLE 1

OBSERVATION NO.	LOAD (KN)	ELONGATION (MM)	STRAIN	STRESS
1	0	0	0.000	0.00
2	16.55	1.05	0.001	97.52
3	16.6	2.48	0.003	97.82
4	16.75	3.25	0.004	98.70
5	16.85	4.22	0.006	99.29
6	16.95	5.5	0.007	99.88
7	17.05	6.08	0.008	100.47
8	17.6	8.08	0.011	103.71
9	18	9.65	0.013	106.06
10	18.2	10.28	0.014	107.24
11	18.45	11.38	0.015	108.72
12	18.8	12.43	0.017	110.78
13	19.25	14.75	0.020	113.43
14	19.3	15.03	0.020	113.72
15	19.35	15.53	0.021	114.02

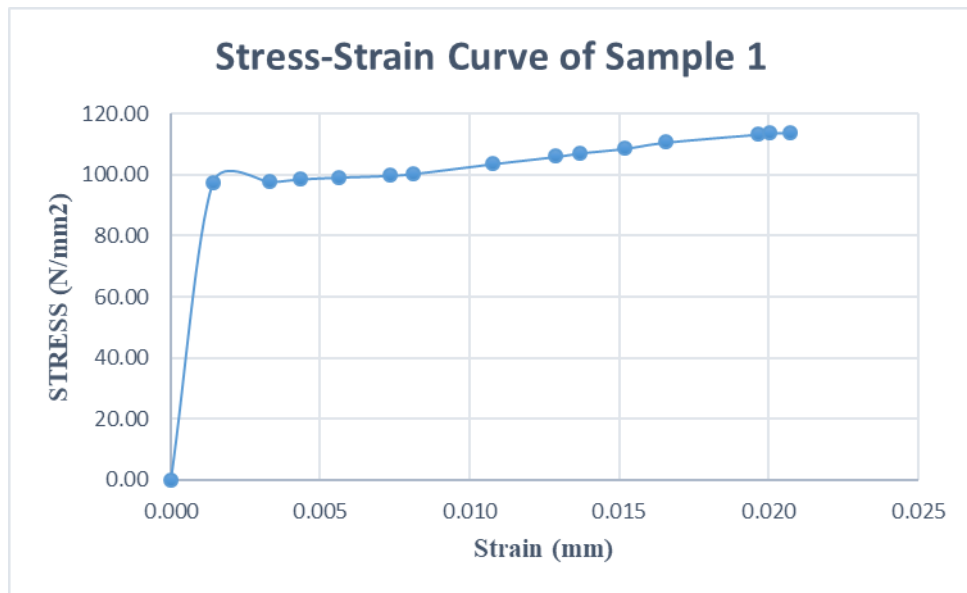


Fig.3: Stress-strain curve of sample1

TABLE III

TENSION TEST RESULTS OF SAMPLE 2

OBSERVATION NO.	LOAD	ELONGATION	STRAIN	STRESS
1	0	0	0.000	0.00
2	17.45	0.57	0.001	102.82
3	17.9	3.53	0.005	105.48
4	18.15	4.41	0.006	106.95
5	18.4	5.98	0.008	108.42
6	18.6	8.6	0.011	109.60
7	19	11.3	0.015	111.96
8	19.2	13.63	0.018	113.14
9	19.65	18.63	0.025	115.79
10	19.8	18.94	0.025	116.67
11	19.9	19.43	0.026	117.26
12	20.05	20.69	0.028	118.14
13	20.35	22.78	0.030	119.91
14	20.5	23.1	0.031	120.80
15	21.65	27.08	0.036	127.57

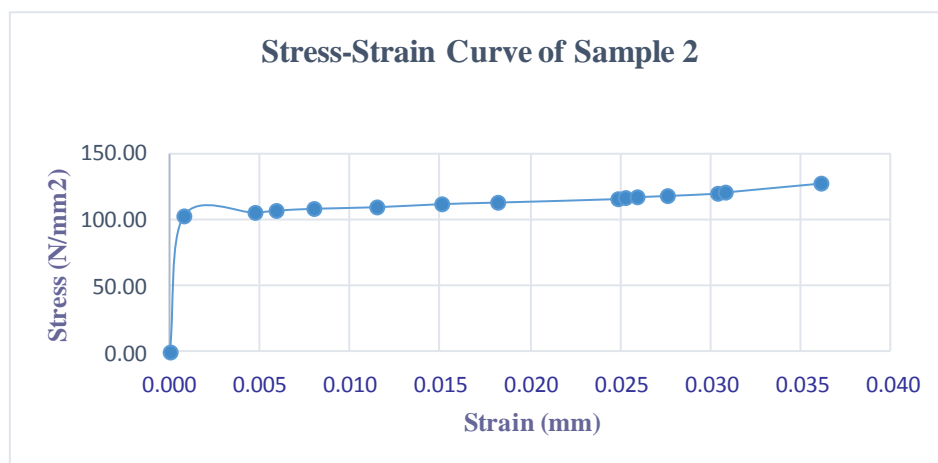


Fig 4 Stress-Strain Curve Of Sample 2

The average tensile strength of bamboo is found out to be 120.79 N/mm<sup>2</sup>.

**III. STRENGTH TO MASS RATIO**

The Bamboo has more than twice the Unit Strength-Weight ratio than that of Steel.

TABLE IV

STRENGTH DENSITY RATIO

SAMPLE	ULTIMATE STRENGTH(MPA)	DENSITY(KG/M <sup>3</sup> )	STRENGTH-DENSITY RATIO
Bamboo	120.79	600	0.2013
Steel	415	7850	0.0528

**IV. COMPARATIVE ANALYSIS**

**A. Co<sub>2</sub> Emission**

For the production of steel and cement tremendous amount of CO<sub>2</sub> is emitted.

TABLE V

CO<sub>2</sub> EMISSION FOR STEEL PARKING

MATERIAL	RATE /TON OF STEEL	WEIGHT OF STEEL	CO <sub>2</sub> EMITTED
Steel	2.89 ton/ton	4.127 ton	11.927 ton

Above table shows that carbon emission by steel parking is 11.927 ton. In-case of bamboo condition is vice versa.

**B. Cost Analysis**

**1) Cost analysis of parking using steel-**

Section- ISMB 150, Hollow Steel Section-25\*25\*2.6mm Used.

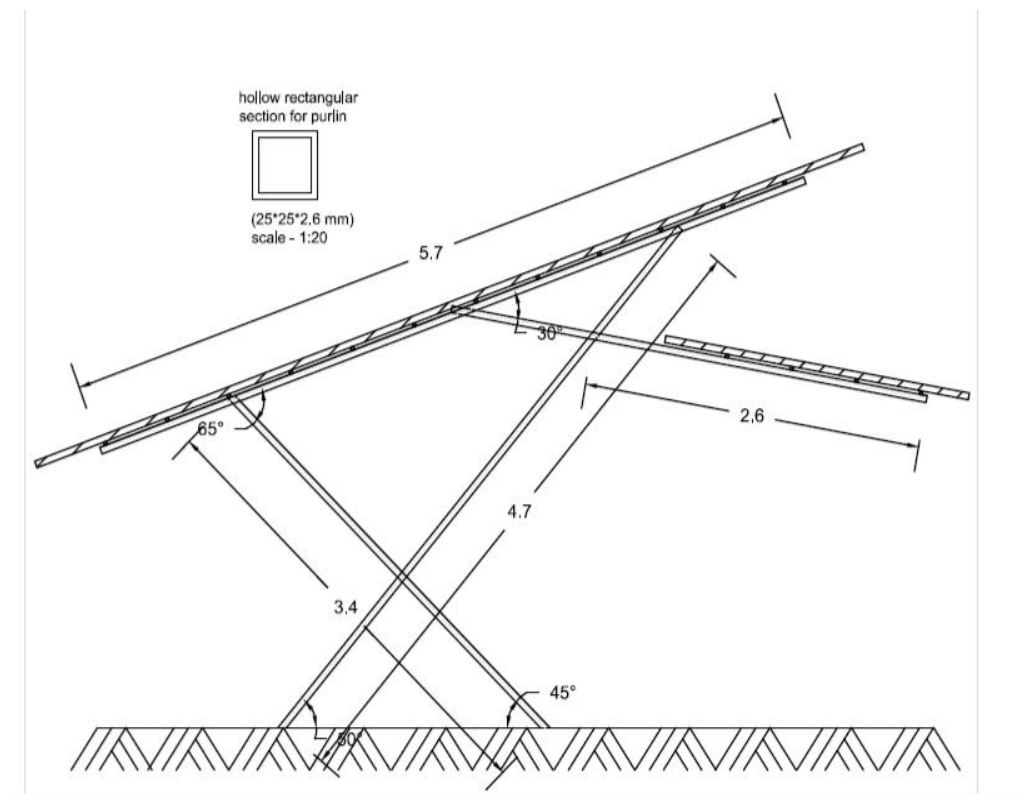


Fig 5: Left hand side view of steel parking

TABLE VI

MEMBERS	WEIGHT PER METER KG/M	COST OF STEEL	LENGTH IN METER	WEIGHT OF STEEL	COST OF STEEL
Column	74.8	35Rs.	$3*(5.7+3.25+5.1+3.5)$ = 52.65 meter	$52.65*74.8=3938.22\text{kg}$	$3938.22*35=\text{Rs } 137837$
Perlin	1.69	35Rs.	$16*7 = 112$ meter	$112*1.69=189.28\text{kg}$	$189.2*35=\text{Rs } 6624.8$
				Total=	Rs 1,44,461.8

ESTIMATE OF PARKING USING STEEL

2) Cost analysis of parking using bamboo

Type of bamboo – Dendrocalamus

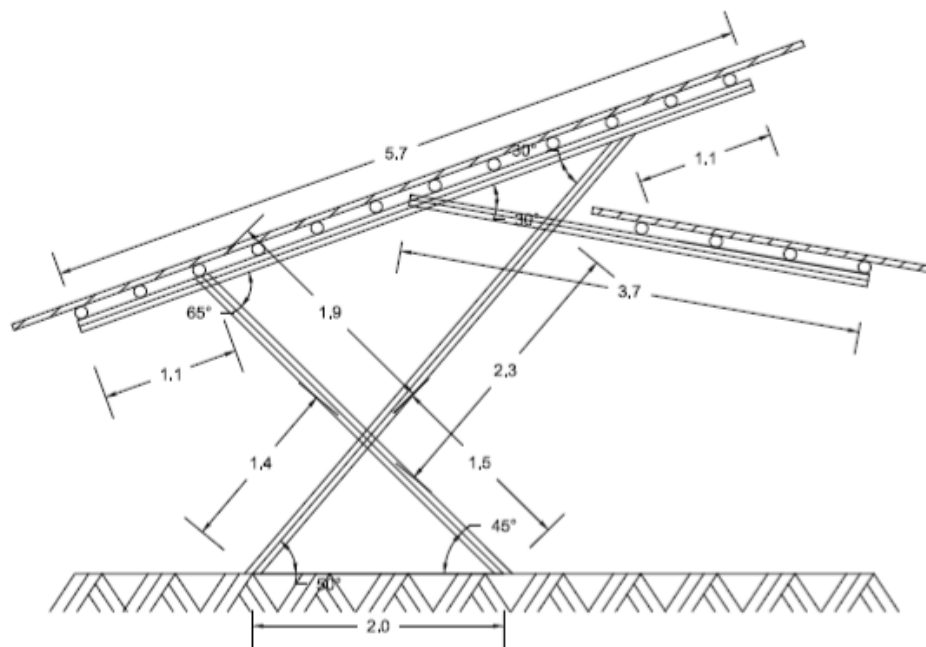
Cost of bamboo – Rs 32/meter

Table VII

ESTIMATE OF PARKING USING BAMBOO

MEMBER	LENGTH OF MEMBERS	TOTAL LENGTH	TOTAL COST
Column	$2*3*(5.7+3.25+5.1+3.5)$ = 105.3	$105.3 + 112 =$ 217.3 meter	$217.3 \text{ m} * \text{Rs.} 32 =$
Perlin	$16*7 = 112$ meter		Rs.7195

The above comparative cost analysis between bamboo and steel shows that construction of parking with steel cost 20 times more than the bamboo.



bamboo parking

Fig 5: Left hand side view of bamboo parking

V. Earthquake Resistance of Bamboo

Bamboo is suitable material for earthquake resistance structure as it has a large elasticity due to its fibrous texture. Questions arises how would it survive during an earthquake of any intensity? For analysing the intensity and damage

caused by earthquake to the structure, typical shock table test is carried out. The test results are very good or we can say that more satisfactory than the expected.

## VI. CONCLUSIONS

1. More than one bamboo samples of species *dendrocalamus stokcsi* have been tested out and analyzed to study their properties.
2. We can use bamboo as tension and compression member.
3. In comparison with Steel, Bamboo has four times lesser strength to mass ratio.
4. CO<sub>2</sub> emission of steel with respect to bamboo is very large.
5. Bamboo structure requires 20 times less cost than steel structure.

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## IS CODE

- i. IS 6874 (2008): Method of tests for bamboo [CED 9: Timber and Timber Stores]
- ii. IS 8242 (1976): Methods of tests for split bamboos [CED 9: Timber and Timber Stores]