Earthquake Response For Bamboo Reinforced Concrete Structures Using Dampers

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Abstract – *Reinforcing steel, used in reinforced concrete worldwide, is expensive. As a result, there is a proposal to use bamboo as a reinforcement in concrete, in the form of culms or strips. Bamboo is a highly renewable and versatile resource, characterized by high strength and low weight, and is easily accessible using simple tools. Numerous studies are being conducted on the productivity and usage of bamboo as a reinforcement. This research paper specifically focuses on the performance of bamboo as a structural reinforcement for five-story buildings under earthquake conditions. The necessary inputs for this research were obtained from experiments and used in the ETABS software to analyze earthquake cases.*

Key Words: Earthquake, Bamboo, Reinforcement, ETABS, Experiments.

1. INTRODUCTION

Generally, reinforcing steel is used as a rebar material for construction. However, due to rising concerns about energy and the environment, searches are going on for non-polluting materials that need less energy. Finding a substitute using all types of waste or fiber is being developed. In this era, the choices of people are categorized on price and quality, but due to lack of awareness and knowledge about available materials, forces people to use industrialized materials. While manufacturing 1kg of steel produces 1.85 tons of carbon dioxide, almost 8 percent of global carbon dioxide emission, while Bamboo emits only 80 times less carbon dioxide. Steel carbon footprints are 2.2-2.8 kg CO_2/kg and 0.25 kg CO_2 /kg for Bamboo. Talking about its mechanical properties, the tensile strength of Bamboo is quite high, and its specific weight is comparatively higher than that of steel, making it an attractive substitute for steel. For Bamboo, the tensile strength-to-specific weight ratio is six times greater than that of steel. [1].

1.1 Strength of bamboo as a construction material

Generally, it is a common practice that an under-reinforced concrete section is preferred for a design in which reinforcing materials yield first that of concrete material which helps to inform the occupants that the building is going to have failure soon. Bamboo is also a brittle type of reinforcing material and failure is not acceptable, either an over-reinforced design is prescribed by which limited ductility is achieved through concrete crushing [2], or the limit of working stress needs to be kept lower than that of ultimate strength such that reinforced section provides clear information before it goes to failure. The average tensile modulus of Gudua Angustifolia type bamboo is on the order of 20 GPA[3], thus the modular ratio Esteel/EBamboo =10.

2. PROPERTIES OF BAMBOO

2.1 Physical Structure of Bamboo

Bamboo is most compared with wooden products because of its similar chemical structure. However, the physical structure of Bamboo is not the same as other wooden members. Wooden products have anisotropic properties, and they contain grains that are oriented in the same direction throughout the complete structure. On the exterior edge of every node, branches form different types of leaf structures that look like grass. Bamboo has parallel fibers that are reinforced along the axial direction of the Culm.

2.2 Shrinkage and Swelling

Bamboo behaves the same as wood and changes its dimension when it loses or gains moisture content. Bamboo is categorized into hygroscopic type material. The moisture content usually changes with having change in the corresponding humidity and temperature of the surrounding atmosphere[4].

2.3 Bending

B Bending is the most important parameter as it is directly related to the material's initial and ultimate strength. The bending property of any member is mostly dependent upon its cross size. Because of this ability, Bamboo can be treated as a substitute for reinforced steel in the construction of buildings[4].

2.4 Elasticity

The enormous elasticity of Bamboo material makes it a very good building material for earthquake-prone areas. Also, Bamboo has very low weight. This helps for smooth transport and works easily, thus the use of cranes and other big machines becomes unnecessary[4].

2.5 Fire Resistance

The fire resistance of Bamboo is very good. The content of Silicate acid present inside it helps to become a good fire resistive material. If the Bamboo is filled up with water, it can stand a temperature of 400° C while the water cooks inside[4].

3. METHODOLOGY

3.1 Experiment programmed

The experimentation has been carried out to know the tensile properties of Bamboo reinforcement. In this experiment, an elongation test was performed using code reference IS 6874:2008. For conducting this experiment, some preliminary treatments were performed on Bamboo surfaces like sampling, chipping, and smoothening of edges, etc.

Fig-01: Sampling and chipping of Bambo for experiment

3.1.1 Experimental methodology

Three Bamboo samples of different diameters i.e., 15mm, 18mm, and 24mm were used for finding yielding property using UTM (Universal Testing Machine). The selection of diameters was nominal just like using bar diameter for G+5 storied building.

Table -1: Tensile strength as per Bamboo diameter

Sample no.	Diameter (m)	Area (mm^2)	Yielding strength (n/mm^2)	Tensile strength (n/mm^2)
1	15	176.71	203.6	217.1
2	18	254.46	233.3	248
3	23	415.47	265	273

Fig-02: Bamboo sample under UTM.

3.2 Software analysis

Software analysis was carried out using ETABS v 21.0 software. A 5-story building was modeled in it with 2 basement floors, 1 commercial floor, and 1 residential floor respectively. The topmost floor is assumed as a roof level.

Nominal thicknesses were assumed for the slab as per conventional Indian buildings which is 225mm. keeping the perspective, floor height kept at 3.2 meters. A parapet of height 1.0 meters was considered on the roof level. Loadings were assumed as per IS 875: 1987.

Table -2: Assumed area loadings

Sr. no	Level	Dead load (kN/m^2)	Live load kN/m^2)
1	Roof	3.75	1.5
2	First	3.75	2.5
3	Stilt	3.75	2.5
4	Basement 1	4	3
5	Basement 2	-	-

3.2.1 Sectional assumptions

- Slabs : 225 mm
- Beams : 250 mm x 550 mm to 450 mm x 750 mm
- Columns : 500 mm x 1000 mm to 750 mm x 950 mm
- Shear walls : 400 mm
- Concrete grade : M50

3.2.2 Earthquake assumptions

- Seismic zone : IV
- Zone factor, Z : 0.24
- Importance factor, I : 1
- Soil type : II
- Response reduction factor, R : 5

3.2.3 Load patterns and load cases assumptions

Table-3: Assumed load patterns and cases

Sr. no	Load	Type	Code referred
1	DL	Dead	-
2	LL	Live	-
3	SDL	Super Dead	-
4	ELX	Seismic	IS 1893.2016
5	ELX+E	Seismic	IS 1893.2016
6	ELX-E	Seismic	IS 1893.2016
7	ELY	Seismic	IS 1893.2016
8	ELY+E	Seismic	IS 1893.2016
9	ELY-E	Seismic	IS 1893.2016

3.2.4 Analysis outputs

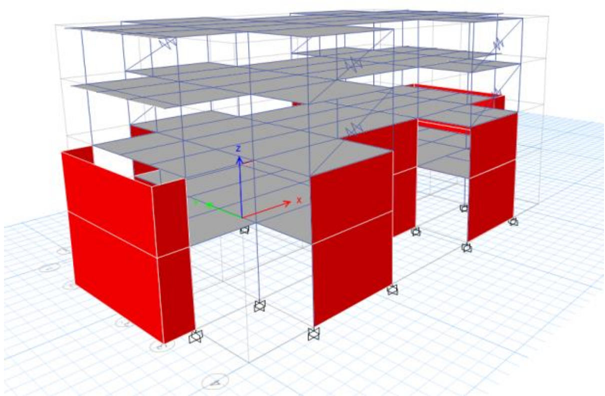

Fig -03: Building 3D model

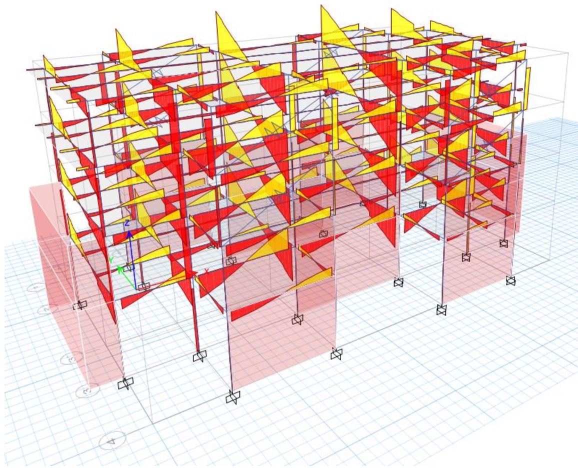

Fig-04: Shear effect diagram

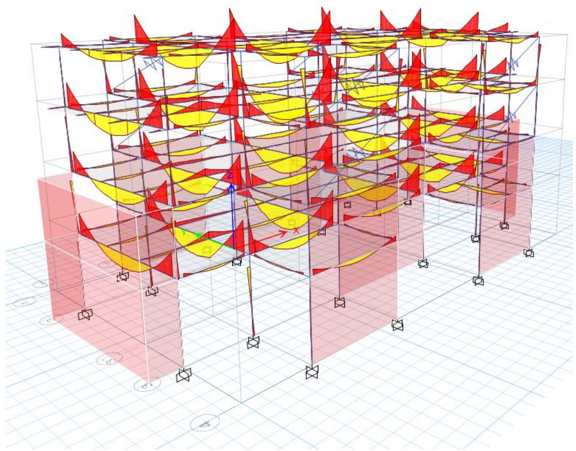

Fig-05: Bending moment diagram

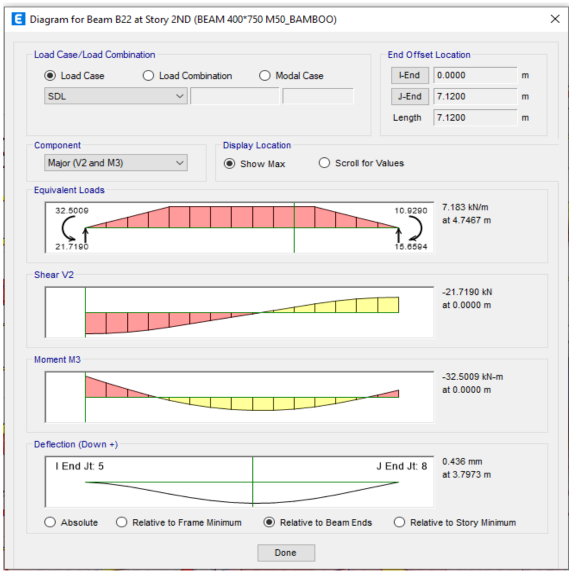

Fig-06: Shear force, Bending moment diagram for Bamboo reinforced concrete beam section

4. RESULTS

4.1 Story Response

Table-4: Story Responses

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
2nd	8.65	Top	0.0005	2.1194
		Bottom	0.0005	2.1194
1st	5.05	Top	0.0008	3.8472
		Bottom	0.0008	3.8472
stilt	1.05	Top	0.0008	4.9497
		Bottom	0.0008	4.9497
b1	-2.9	Top	0.0009	5.524
		Bottom	0.0009	5.524
b2	-8	Top	0	0
		Bottom	0	0

4.2 Overturning moments

Table-5: Overturning moments

Story	Elevation	Location	X-Dir kN-m	Y-Dir kN-m
2nd	8.65	Top	0	0
1st	5.05	Top	-7.7019	0.002
stilt	1.05	Top	-23.2796	0.0054
b1	-2.9	Top	-43.0431	0.0087
b2	-8	Top	-71.4027	0.0131

4.3 Story drift

Table-6: Story drift

Story	Elevation m	Location	X-Dir	Y-Dir
2ND	8.65	Top	9.815E-09	0.000003
1ST	5.05	Top	7.919E-09	0.000003
STILT	1.05	Top	0	0.000002
B1	-2.9	Top	5.791E-09	0.000001
B2	-8	Top	0	0

3. CONCLUSIONS

The study suggests that with proper design, detailing, and placement of dampers, bamboo-reinforced concrete structures can meet the necessary safety standards for seismic zones. However, it also highlights the importance of further research and real-world testing to optimize the design parameters and to address any long-term durability concerns related to bamboo reinforcement. Also, Bamboo's rapid growth rate and low cost, coupled with the energy-absorbing capabilities of dampers, provide a cost-effective solution for earthquake-resistant structures. This combination not only reduces construction costs but also aligns with green building practices, contributing to lower carbon emissions and reduced environmental impact.

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