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Seismic Behavior of Bamboo and Steel: A Shake Table Comparison

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ABSTRACT

The elastic properties of bamboo have been studied recently and shown to improve the seismic performance of bamboo buildings compared to those produced using traditional materials. In this study, we analyse how well a bamboo building can withstand earthquakes. Bamboo was selected because it is carbon sequestrate, inexpensive, readily accessible, biodegradable, and flexible (making it suitable for usage in seismic zones). Strict similitude criteria and a battery of dynamic testing will inform the model's development. After the model has been built using Bamboo, it is subjected to frequency range testing on a shaking table. The model is evaluated by recording the drift, displacement, and acceleration data at various frequencies. The key to successful testing is design similarity. Detailed plans and instructions for making a miniature replica of a Bamboo building are going to be presented. Providing protection against earthquakes, bamboo bands are installed at lintel and plinth levels in earthquake-prone Himalayan regions of India. This work makes use of and is based on experimental data. The experimental structure was made up of two three-story, single-bay Bamboo frames.

Keywords: Seismic Performance, Shake Table, Bamboo, Displacement, Stiffness.

INTRODUCTION

The bamboo plant plays a significant role in both agriculture and forestry. Many people in the Asia and Pacific area rely on it for their social, economic, and ecological well-being. For hundreds of years, people have used bamboo to construct huts and homes out of mud. It's a green material that lasts and bends with you, and it's sturdy and versatile to boot[1]. As one of the world's fastest-growing plants, bamboo may go from seed to harvest in only 120 to 150 days. With other trees, you'd need to gather for 10–30 years to get the same amount of material as you could in 3–5 years with bamboo [2].

In the range of 30–121 Mg/ha, bamboo is capable of storing and sequestering carbon at an impressive rate. Their great carbon sequestration capability is due to their large biomass buildup and

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efficient carbon (CO2) fixing. It's very productive, and even after being cut down, it can be used as a carbon sink and will continue to expand. What Bamboo Is and What It Can Do Shoots refer to juvenile bamboo stems, whereas culms refer to more mature stems. There are two primary components to a bamboo plant. As a culm or stem, it develops above earth. The rhizome is a rootless, subterranean stem that may produce new shoots. At the end of its life cycle, a single bamboo plant may provide a pole as long as 15 kilometres (30 centimetres) in India [3].

Structure

Their culms are hollow and inside split into several diaphragms that give the impression of rings from the outside. The inter-node, from which new branches will emerge, is located between every pair of rings. Numerous vascular bundles may be seen in the microscopic structure of the culms [4]. They are dispersed vertically inside the parenchyma tissue of the wall.

Characteristics

• It's one of the quickest-growing plants around.
For starters, there are over a thousand different species spread over 70 different families.
• Its growth cycle is very rapid, reaching up to 70 mm each day and reaching up to 350 to 450 mm in a single day.
• Their diameter ranges from 29 mm to 300 mm, making them somewhat cylindrical in form.
Sixty-six percent to seventy-percent of bamboo is made up of fibre.
Properties
Both tensile and compressive forces [5]
The tensile and compressive strengths of bamboo are exceptional. Bamboo's fibres run axially, giving the outer zone tensile strength. Its tensile strength varies with its height. Compressive strength rises with bamboo height, but bending strength decreases with height.
• Elasticity [6]
Bamboo is a sustainable building material since it has a low carbon footprint and excellent elastic properties.
• Shrinkage [7]
When exposed to moisture loss, bamboo contracts more than wood.
• Resistibility [8]
A
s a result of its high silica acid content, bamboo has excellent fire resistance.
Bamboo has several applications: it may be used as a building material, in the creation of furniture, in the manufacturing of paper, textiles, and drugs, and in the manufacture of everyday household products.

Examination and Model Construction

Theoretical and practical considerations make the creation of a bamboo scale model a sensitive task. In this scenario, a model is being tested that consists of three-story, single-bay bamboo buildings. The original, huge version of this device is somewhat hefty. Beams and columns, both horizontal and vertical, are modelled and scaled here.

Each component of the framework—columns, beams, connecting bolts, and rivets—is carefully

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designed to work together.
Both the mass and the degree of stiffness are set in stone.

First, fresh bamboo is gathered from the area to be used in the model's construction. After collecting the bamboo, the dimension determined by the scaling factor is recorded. Once the bamboo has been cleaned, it may be cut into the necessary proportions and forms to make the needed model. We've got rivets for you anywhere you need a fastener.

The seismic analysis is performed on this scaled and simplified model, and the findings are compared to those obtained with the actual prototype. Acceleration, velocity, and position as a function of time are all components of the final outcome.

Material Constant of elasticity (MPa)
In this case, a three-story, one-bay structure was used as a prototype. The characteristics of the prototype serve as the foundation for the design of the model.A three-story residential structure serves as the template here. The dimensions, elastic modulus, acceleration, and density of an object all play crucial roles in the scaling factor of a shaking table test. Acceleration, displacement, and other relevant parameters were recorded during testing of two models exposed to the vibrations.Scaling is accomplished by adjusting the length scaling factor (SL) and the elasticity scaling factor (SE) in the prototype and model, respectively.

When the appropriate scaling factor has been determined, the scaled model may be assembled. This is how the model is set up,The prototype structure is analysed initially.

Once the prototype has been built and scaled to the correct proportions, a model may be obtained.After settling on a suitable scale for our bamboo model, we proceeded to its construction.The essential parts of the model are the columns, the foundation and story plates, the steel nails, the bamboo (if it is a bamboo model), and the steel (in case of steel model).We scoured the area for bamboo and then harvested and sanitised the necessary quantity.Then the bamboo is cut into desired shape and sizeBamboo is used to build columns that are 400 mm in height (one story high), 3 mm in thickness, and 25 mm in width.The dimensions of the plates are 300 mm in length, 150 mm in breadth, and 12.5 mm in thickness.

Since the plate's thickness and breadth are both rather high, we used five 30 mm wide bamboo strips to make the plate 150 mm wide and two 10 mm wide strips to make up the plate's thickness.Glue and metal wires were used to join the bamboo strips together.The model can be securely placed on the shaking table thanks to the 12mm-diameter holes drilled into the base plate (here 12mm diameter bolts are used).Each component of the model is meticulously prepped before being assembled to form a scale duplicate of a structure with three stories and a single bay. In this case, steel nails are utilised to fasten the parts together. When the simulation is complete, the model may be securely mounted on the shaking table for further testing. The Shake Table Test In reference to the shaking table. This portable vibration analyzer may be used to analyse the movement of structural models and in a wide range of mechanical and civil engineering investigations. It offers a wide variety of options for achieving that goal. All processing is done digitally except for some

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filtering that occurs in an analogue form. The internal flash memory makes it simple to record data and transfer it to a personal computer. Aside from the standard frequency-domain display, the device also has an FFT analyzer mode. Acceleration, velocity, and displacement are all measured and presented concurrently in the time domain, and frequency may be shown as well. In analyzer mode, the power spectrum and vibration waveform are analysed using FFT. Before doing FFT analysis, the signal-to-noise ratio may be improved by applying digital filters to restrict the bandwidth.

Acceleration, velocity, and distance all shown at the same time. Online parameter monitoring in real time. The signal-to-noise ratio is improved through digital filtering. Analysis by FFT Easy to use with little adjustments needed. Data flow management internal buffer. Temporary information storage that is performed automatically. The capacity to capture and analyse data without an internet connection. With USB2.0, serial data transmission may be done quickly and efficiently. The intuitive graphical user interface makes it simple to use and understand quickly. Lightweight and convenient to carry everywhere.

MILDAQ Vibration Analyzer Block Diagram (Shake table)

Using a Shake Table for Testing

This is the shaking table testing technique. Both softwares are supported.If you have the Kampana Vibration Analyzer software installed, you may access it by double-clicking its icon on your computer's desktop.Following the program's start, go to the Settings menu and make the necessary selections there, including those for the com port, channels, and grid.If you want to see a visualisation of time domain data, use the play button.The frequency must be checked. A frequency shift should be preceded by at least 20 seconds of dead air; a full minute is a more reasonable benchmark.The display windows' time and voltage scales may be adjusted using the keys.To apply a filter, first turn it on by clicking the Filter ON button, then click Filter Settings.Observe the time domain waveform to observe the evolution. Alterations in the time domain will be mirrored in the frequency domain.Verify the vibration settings in the interface.In order to ensure that the data stored is accurate, choose the Log mm/Hz tab.If you want to experiment with a different frequency range, just replace the 4th step with your new frequency and continue from there.To conduct further experiments, just return to Step 4.You may halt the study by using the pause button.Examine the stored files in the default location, and make sure you're looking at the right time and date.In order to double-check the information, read it and plot it offline.Take a look at the acceleration, velocity, and displacement time series in the produced file once you've exported the data on acceleration.STAAD.The prototype has been analysed using STAAD.pro, and the findings may be seen. Here we see the displacements for the lower levels (CH1-X,Y,Z), and as we travel higher, it grows along the upper levels (CH2-X,Y,Z) (CH3-X,Y,Z).

EXPERIMENTAL FINDINGS

The Results of Experiments on Bamboo

Using the frequency-dependent displacement values from table 3, the following graph was created for channels 1-X through 4-X. The frequency range here is from 2.5Hz to 9.0Hz. Tests on a shaking table show that the model moves less as the frequency increases up to 2.5 Hz, then more after 2.5 Hz, and finally less again as the frequency increases to 4.5 Hz. The displacement also varies

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continuously. Bamboo can withstand vibrations up to 9.0 hertz.

Displacement values at different frequencies for channels 1-Y through 4-Y are used to create the graph below. The range of frequencies in this case is from 2.5Hz to 9.0Hz. Tests on a shaking table show that the model moves less as the frequency increases up to 2.5 Hz, then more after 2.5 Hz, and finally less again as the frequency increases to 4.5 Hz. The displacement also varies continuously. Bamboo can withstand vibrations up to 9.0 hertz.

Research on Steel from Experiments

In order to see the effects of frequency changes on displacement, we plotted the results for channels 1-X through 4-X below. Here, the frequency shifts occur between 2.5Hz and 8.25Hz. The results of shaking table testing show that the model's displacement is minimal up to 2.5Hz, increases to a maximum at 3.5Hz, and then decreases again till 6.5Hz. The displacement also varies continuously. Up to 8.25Hz, steel is capable of withstanding the frequency.Displacement values at different frequencies for channels 1-Y through 4-Y are used to create the graph below. The range of frequencies in this case is between 2.50 and 8.25 hertz. We found that the model's displacement was most at 2.5Hz, then decreased again as the frequency increased to 6.5Hz during our shaking table testing. The displacement also varies continuously. Steel can take in sound up to 8.25 hertz.

Indicative Comparisons

The maximum displacement values for bamboo were found to occur at 2.5Hz and 9.0Hz, whereas the maximum displacement values for steel were found to occur at 2.5Hz and 8.25Hz, as shown in the corresponding displacement vs. frequency graphs.With the use of the above comparison graphs, we can clearly conclude that the displacement seen in the case of bamboo is smaller than that of steel for all the key portions such as CH-1X, CH-2X, CH-3X, and CH-4X. Like bamboo, steel exhibits significant displacement in similar frequency ranges.

CONCLUSIONS

The following inferences may be drawn from the aforementioned research, graphics, and outcomes. After comparing all of steel and bamboo's fundamental qualities, it was determined that bamboo was more adaptable. The lower displacement values seen in bamboo in comparison to steel indicate that the material has excellent elastic properties. We may conclude that bamboo has high tensile and compressive strengths from the aforementioned investigations. We may deduce that the displacement curve for bamboo is showing smaller values and that for steel is showing larger amount of displacement after looking at the graphs made to the displacement values of steel and bamboo at crucial sections (comparative graphs). To put it another way, bamboo can withstand a great deal of earthquake energy. As was noted before, bamboo has a rapid growth rate, sometimes exceeding 70 mm per day and more often reaching 350–450 mm. Bamboo is a versatile and inexpensive building material that thrives in a wide range of environmental conditions and can be readily shaped and flattened after construction.

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