



Study of Bamboo: Earthquake resilient building material.

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Abstract

Global warming and deforestation are the reason for climate change across the world. The whole world is moving towards sustainability and renewable energy. Construction Industry alone creating huge amount of pollution which is adding to the global warming. Due to Global warming across the world we are experiencing weather change in terms of Temperature, sea level rise, earthquake etc. There is no tools has been developed to predict the earthquake. Due to earthquake vibration the whole world goes through huge financial and human life loss.

India consists of five seismic zone. And if we have to by the facts, many Indian megacities are on threat of earthquake. The psychological trauma of the earthquake survivor is beyond our thinking as the loose everything from home to family. In this situation they need a home and support to gain back their moral to fight with the situation and overcome. The bamboo House is cost effective and quick completion, which can provide an immediate shelter to the needy.

The Bamboo is a renewable resource and requires very less energy for construction. It does not require specialized tools for building construction and available at very less price compare to Conventional masonry structure, which makes it as cost effective material. Many research has been carried out to establish the mechanical strength of bamboo. Which proves that the bamboo is safe for building construction. The threats of durability also has been removed by using proper treatment. The Assam-type houses are best suitable example of bamboo houses. These houses demonstrate The simple geometry, low rise, grass infill, flat land are the ways to create cost effective earthquake resistant building.

Index Terms : Earthquake, Bamboo, Sustainable Material, Cost effective, Low Rise building.

I. Introduction

In the history of human evolution the bamboo is been an integral part of human life in many ways from Food to weapon. Bamboo is a grass having multiple joints namely culms solid nodes (Figure 1). Bamboo also used as recourse for many daily essential products.

Bamboo's natural growth is very high, it can grow from 7.5cm to 40cm in a day. [3]

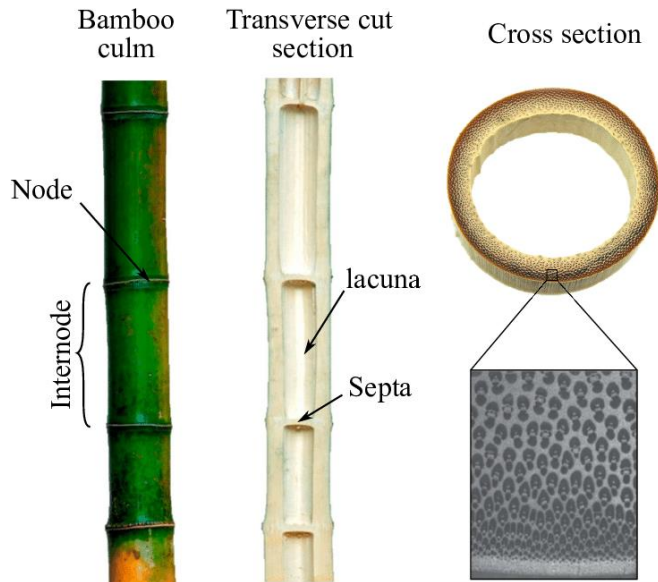


Figure – 1 : Cross section of Bamboo

Today, bamboo is used for many uses including construction of houses and multi-storey building. The Availability of bamboo and its strength has made it as alternate building material. It has various other quality which make is more appropriate for building construction such as Light weight, cost effective etc. The bamboo has gained popularity for building construction because it requires simple tools to work with. Use of bamboo is considered as sustainable practice due to its local availability.

The global warming is big problem in front of the mankind, sustainable practice is the only way by which we can control global warming. The more we

play with nature more problem will occur. Improper uses of natural resources causing mean sea level rising, high temperature, melting glaciers, Tsunami and Earthquake.

The India and neighbouring country like Nepal, Pakistan, china has history of facing many disastrous earthquake, the recent earthquake has happened in 2001, also known as Bhuj earthquake. Total 20000 people were died and 1,50,000 people were injured. [11]

Majority of built Structure are not comply the Earthquake resistant building as per Indian bye-laws. The non concrete houses were made up of mud and field stone. The Concrete houses were made up of cement mortar, brick block and cut stone. Majority of Kach population were living in kaccha houses and few in pucca houses. 187,000 pucca houses collapsed and 500,000 were severely damaged, while 183,000 kaccha houses collapsed and 420,000 experienced moderate to severe damage [2].

The aim of this research paper is to study about Bamboo's potential as resilient building material for Earthquake prone zone. The objectives behind this research paper are:

- I. To study properties of bamboo.
- II. To study Sustainability aspect of Bamboo.
- III. To study Indian seismic zone.
- IV. To study the impact of earthquake on society.

Many researchers are discussing on the earthquake resistant building with many modern technology from low rise to high rise building such as Footing isolation or dampers. But all the techniques are expensive and also it requires technical knowledge. Where we should provide a cost effective solution to the mankind so that everyone can utilize. It has to cost effective, simple, local available material and easy to work.

II. India and seismic threat

There are total five seismic zone are there in India. The country has faced multiple disastrous earthquake in last100 years, out of which in 1934 Bihar earthquake and 1950 Assam earthquake are memorable due to its intensity and loss of life.

The earthquake happens due to the friction of tectonic plates, there are no tools developed yet to predict earthquake. India is seating on Minor Tectonic Plate. Once upon a time, India plate was part of ancient Gondwana continent. 100 millions year ago it got separated and moved to North.

(Source: https://en.wikipedia.org/wiki/Indian_Plate)

Due to plate tectonics, the India Plate split from Madagascar and collided with the Eurasian Plate, resulting in the formation of the Himalayas.

(Source: https://en.wikipedia.org/wiki/Indian_Plate)

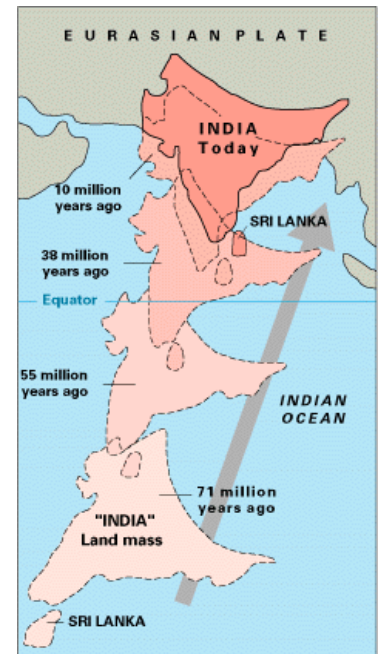


Figure - 2

Figure – 2 showing The Indian Plate is currently moving north-east at five centimetres per year.

The collision with the Eurasian Plate along the boundary between India and Nepal formed the organic belt that created the Tibetan Plateau and the Himalaya Mountains, as sediment bunched up like earth before a plough.

(Source: https://en.wikipedia.org/wiki/Indian_Plate)

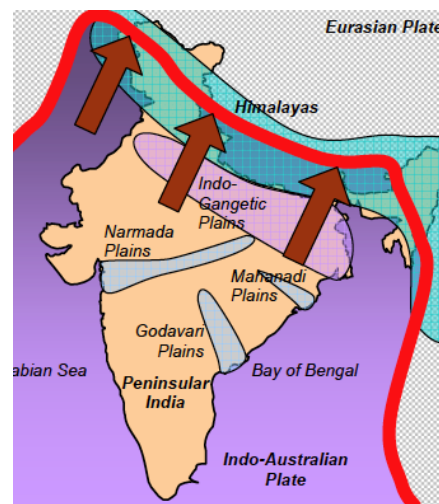


Figure - 3 : Geographical Layout and Tectonic Plate Boundaries at India

(Source: C.V.R.Murty, Indian Institute of Technology Kanpur, Kanpur, India)

III. India and seismic Zone

Seismic Zone	Intensity	Intensity on Modified Mercalli scale*
Zone V	Very severe intensity zone	IX and above
Zone IV	Severe intensity zone	VIII
Zone III	Moderate intensity zone	VII
Zone II	Low intensity zone	VI
Zone I	Low Damage Risk	V or Less

*measures the impact of earthquakes on the surface of the earth

Table -1: Indian Seismic Zone [12]

IV. After Earthquake

The effects of earthquake is not limited only during the earthquake. it has bigger impact on the earthquake survivor. The Psychological trauma after losing their family members, house etc. is break down their moral. In This situation they look for the help and support. A home is a basic need for human, but creating a conventional material house requires more time and money. The cost effective building material and speed of work may be helpful for the survivors.

Bamboo can be recommended, Since Bamboo is locally available, Sustainable green material and strong. It is recommended for use as horizontal members less than 3– 3.6mlong without middle support [7]; A study showed that the tensile strength of bamboo is about 28,000 N/m² (0.028 MPa), which is similar to steel [13].

Bamboo is considered as sustainable building material because of its local availability, environmental benefits and low cost benefits. The current trend in the past four-five decades has led to change in the forms in which bamboo is used and the final outlook of the house has changed a lot as well. Figure 4 (a – c) show the progression of bamboo use from traditional to current style. [8]



(a)



(b)



(c)

V. Properties of Bamboo

Bamboo has strength properties which are excellent, particularly with regards to the tensile strength [14]. The strength of the varies based on the type and species of the bamboo. The outer zone of bamboo has a highly elastic vascular bundle, which also have high tensile strength while the fiber of bamboo run axially, making it more resistant to tension than compression. The high tensile strength of this bamboo fibers is usually higher than that of steel but has a disadvantage of not being possible to construct connections that can transfer this tensile strength. [3]

Bamboo has a property which makes it shrinks more than timber as it loses its water content. The canes of the bamboo can tear apart at the nodes making it shrink in the cross-section ca. usually between 10-16%, and wall thickness ca. of between 15-17% [3].

To prevent from shrinking, the preventive measure to taken to stop the loss of water.

Bamboo has an excellent fire resistivity due to the high content of silicate acid it possesses. Bamboo which is filled up with water can usually withstand a temperature of 400° C while the water cooks inside. It also possesses high moisture content, which is influenced by the age, species as well as the season of harvesting. Although unlike timber, bamboo starts shrinking above the fiber saturation point, the use of Ecology Diversity Synergy technology has remedied this weakness, as EDS treated bamboo is as durable as solid timber for building construction [15].

Bamboo as a building material in trend and being adopted for all kinds of building, including modern building, such as pavilion, arena. Low rise housing, group housing, farm house etc. The light weight is one of the advantages for earthquake prone area. In fact the earthquake resistant building also recommends light weight material for less harm to the society after earthquake. The flexibility to work with bamboo is have added advantage, it can be fabricated at site or at workshop. Transportation is not the big problem due to its less weight. The longevity of the bamboo also can be increased by providing proper treatment by which the shrinkage issue can be resolved, also it will keep safe from insect attack. Infill is another solution to increase the strength and age as well.

VI. Bamboo: Renewable resource

Bamboo can be harvested in planned manner for better production, when it is harvested systematically, it can reduce the damage to the nature compare to other building construction material. Maintaining its shoot periodically in sustainable manner can produce huge quantity of this sustainable material for building construction. The Growth rate of bamboo is very high, it also can help in reforestation with other species of plants and trees.

VII. Environmental impact

Bamboo is considered as eco friendly material due to its high growth properties. The more uses of bamboo can reduce the threats on many trees, which can help to stop deforestation. The mass level bamboo harvesting and uses of it can provide employment to many and improve the socio economic status of the farmers.

By growing, bamboo takes in carbon dioxide and it in turn gets stored when used in the building. Although, bamboo lasts only 2– 3 years in its natural form, chemical treatments to protect it from natural pests and the use of proper design elements to protect it from effects of climate can make bamboo last up to 30– 40 years. Thus, when bamboo is used in a building, carbon is stored and not released into the atmosphere until the end of the life of the building. The carbon storage and sequestration rates for bamboo is 30– 121 Mg per ha 6– 13 Mg per ha per year, respectively [16].

VIII. Seismic resistance

Bamboo has high strength and low weight, which increases the building's resistance to seismic impact. With proper anti-corrosion treatment, the building will not collapse even in the event of a strong earthquake. For example, in 1991, Costa Rica was hit by a 7.7 magnitude earthquake. The buildings in the epicentre of the usual concrete and brick were completely destroyed, and the buildings made of bamboo had only minor damage.[1].

IX. Bamboo a Resilient material

The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. It is as strong as mild steel with the compression strength of concrete. Amazingly, one inch of bamboo can hold up to 7(1/2) tons of weight [2].

Bamboo is a perfect material for earthquakes: it is lightweight, and the hollow form gives much stiffness. The natural characteristics of bamboo being light in weight, fibrous in morphology, tensile strength makes it

highly flexible material. Bamboo building if properly constructed becomes inherently resistant to lateral shock waves of earthquake forces without failing to large extent [5].

X. Ways of connecting nodes

The main ways of connecting structural nodes are shown in Figure 5.

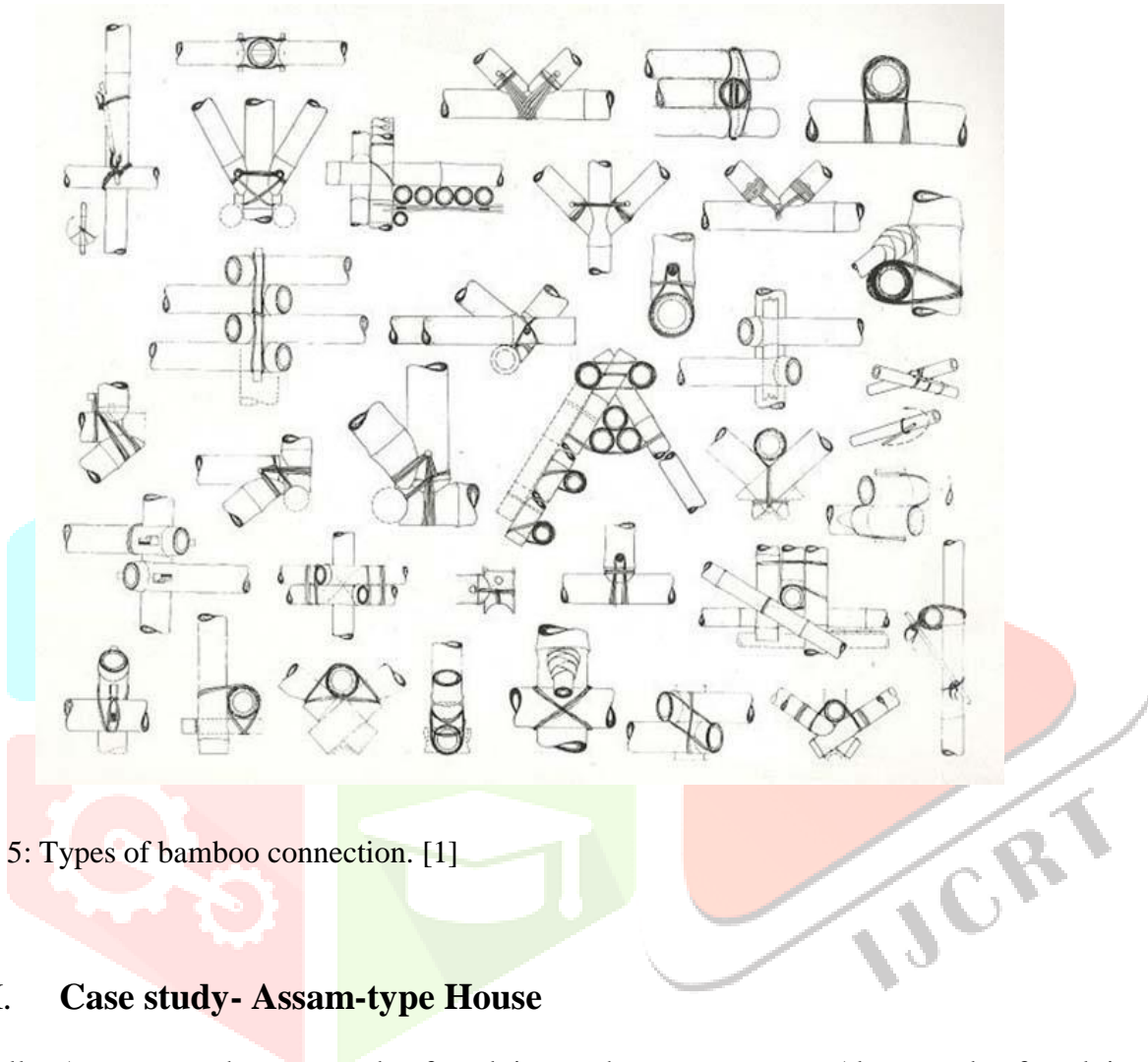


Figure 5: Types of bamboo connection. [1]

XI. Case study- Assam-type House

Generally Assam-type house can be found in north-eastern states. Also can be found in, Bangladesh, Myanmar, Cambodia etc. Most commonly, It is single story high building, also two story building can be seen but not so common. The Wall is made of bamboo in filled with Ikra grass, which available in Ganges plane, it can be plastered from our side. The Ikra grass is used for roofing as well. Some of the houses can be seen with metal roof, depending on their financial status.

These houses can be built on any kind of terrain. They do not share common walls generally these houses maintain a distance of 10m -15m from each other. Assam houses are generally found in rectangular shape for single family. L-Shape and C-Shape also can be found for large families. The door and windows are small in size and are generally placed in the centre of the room. Windows are about 900 mm x1200 mm in size and the door about 900 mm x2100 mm.

The non complex geometry of Assam type houses demonstrates the basics of earthquake resistant building. The reason why masonry building fail is to not having proper connection with each other and due to seismic vibration masonry joint fails and building collapse. The non engineered house such as Assam Type houses are having simple shape, form and sitting firm on the ground which acts as one entity during seismic vibration.

There no such house can be made which is 100% earthquake proof. But the advantage with bamboo is, its very light weight material and locally available, even it falls the less can be expected and the material can be reused for new construction, depending on the age and individual unit damage, full or partial.



Picture 6: A typical Assam-type house.

XII. Inference

There are several reason for such kind of disaster, such as low grade material, no seismic effect calculated while designing the structure, the gap between the building are too less. The threat is even more for heritage building where retrofitting is not possible. To overcome from this kind threat, all central Government, State government and individual house owner need to come together and understand the seriousness of it and work accordingly. Safe construction using sustainable material may reduce the loss of life and built structure. Earthquake resistant building using sustainable material is the answer for challenges and difficulty faced after earthquake.

Bamboo is not just the sustainable material, it also helps the society to improve socio-economic status.

XIII. Conclusion

Human has developed many tools for all purpose but till date there is no machine developed to predict earthquake, location and its intensity. So we have to create our building which can sustain the shake. It is difficult to construct 100% shake proof building but by following some basic rules of earthquake resistant building we can build the building which can cut down the damage drastically. Bamboo being alternate building material having multiple advantages like light in weight, mechanical strength, Green Material, Locally available, renewable material, etc. can give us the built structure which more sustainable during shake and less damage to human life. Bamboo is a material which is truly a green material and can make any architecture to function as it is planned. It also helping to improve the socio economic status of the farmer and reducing deforestation. . The Assam-type house case study suggest that the simple geometry on plain flat land

is best suitable to survive earthquake vibration. It also proves that the light material is more suitable for earthquake prone areas.

References

- [1] A P Lapina and N I Zakieva, “Bamboo in modern construction and architecture” 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1083 012019.
- [2] Archana Baghel, Amruta Thakkar, “Bamboo: A Resilient Material for Mass Housing in Earthquake Prone Zones of Gujarat”, Intrnational conference , IIT Roorkee, Department of Architecture and Planning, Feb,2017.
- [3] Faisal Koko, Panshak Dakur,“Bamboo as a Sustainable Material for Building Construction in Nigeria” Civil and Environmental Research www.iiste.orgISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
- [4] Mir, S. H. (2013). Bamboo as a Cost effective Structural Material in Buildings. International Journal of Engineering and Technical Research, 1(9), November 2013, 4549. Retrieved December 12, 2016, from https://www.erppublication.org/admin/vol_issue1/upload%20Image/IJETR011939.pdf.
- [5] Mukhopadhyay, P. (2008, October). Role of bamboo in seismic architecture. IA&B.
- [6] Mr. Nitin Kumar, Mr. Utkarsh Mathur, Mr. Bharat Phulwari, Mr. Amit Choudhary, “BAMBOO AS A CONSTRUCTION MATERIAL” IJARIIE-ISSN(O)-2395-4396, Vol-3 Issue-1 2017.
- [7] Nwoke, O. A., and B. O. Ugwuishiwu. 2011. “Local Bamboo and Earth Construction Potentials for Provision of Affordable Structures in Nigeria.” International Journal of Sustainable Construction Engineering and Technology 2 (2): 17–31.
- [8] Rashmi Manandhar, Jin-Hee Kim & Jun-Tae Kim (2019) “Environmental, social and economic sustainability of bamboo and bamboo-based construction materials in buildings”, Journal of Asian Architecture and Building Engineering.
- [9] Suchampa Bagchi, R Rashmi Mano, N Thangam, ,“Bamboo as a Building Material “*International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137 Volume – 03, Issue – 07, July 2018, PP – 17-19*
- [10] United Nations Industrial Development Organization (2009). “Bamboo: An untapped and amazing Resource”. Retrieved. March 18, 2018.
- [11] <https://www.britannica.com/event/Bhuj-earthquake-of-2001>. Accessed on 29-07-2021
- [12] <https://www.indiaspend.com/38-indian-cities-in-high-risk-seismic-zones-17989>
- [13] Esti Asih Nurdiah,” The Potential of Bamboo as Building Material in Organic Shaped Buildings” ScienceDirect; Procedia - Social and Behavioral Sciences (2016)
- [14] Madhukar Wakchaure, Sunil Kute;” Performance Evaluation for Enhancement of Some of the Engineering Properties of Bamboo as Reinforcement in Concrete” Journal of The Institution of Engineers (India), November 2014.

- [15] Ogunwusi, A.A.; “Bamboo: an alternative raw material for textiles production in Nigeria” Chemistry and Materials Research, ISSN 2224- 3224 (Print) ISSN 2225- 0956 (Online), Vol.3 No.11, 2013.
- [16] Arun Jyoti Nath Rattan Lal, Ashesh Kumar Das “Managing woody bamboos for carbon farming and carbon trading, Global Ecology and Conservation, January 2015.

