



FEASIBILITY OF BAMBOO AS CONSTRUCTION STRUCTURE MATERIAL IN UTTAR PRADESH

Study of Bamboo that can use as Construction Alternative Material

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Abstract: Bamboo is a locally available sustainable material and uses in many forms and shapes. It is available in Uttar Pradesh and also, NBM cultivated bamboo in many cities of Uttar Pradesh to promote the production and marketing. It is a cost-effective material and can be used as an alternative material.

Keywords - NBM: National Bamboo Mission, Cultivation, Production, Alternative Material, Cost-effective

I. INTRODUCTION

Bamboo is a sustainable and renewable versatile material. It is a fast-growing plant and grows in every part of India which is easy to bend and lithe. It increases the durability after the treatment by borax, boric acid and other types of treatments and also is a fire-resistance material because moisturizer content is high. Bamboo is a locally available material so, its carbon footprint and embodies energy are low. It is also considered as low-cost material and also called 'Green gold' and 'Timber for the poor man'. It is the Traditional house building material but after the industrial era, it has become obsolete. But nowadays, as global warming and sustainability issues have emerged, so Bamboo as a building material is discussed and reviewed for construction. ("2015-Bamboos-in-India," n.d.; Sharma, Dhanwantri, and Mehta 2014)

2. AIM

To understand the use of Bamboo as a sustainable alternative building material in Uttar Pradesh.

3. OBJECTIVE

1. To study and analyse the bamboo species that are cultivated and marketed by National Bamboo Mission.
2. To study and analyse the mechanical properties of Bamboo.
3. To study and analyse the sustainability and economical properties of Bamboo.
4. To study and analysed the seasonings of Bamboo.
5. To study and analysed cost comparison of small houses compared to bamboo and other conventional material.

4. LITERATURE STUDY

4.1. Availability of bamboo in Uttar Pradesh:

Availability of bamboo in the tropical and subtropical regions of the world. 0.54% availability of bamboo in Uttar Pradesh but NBM targeted to cultivate good quality bamboo in Allahabad, Bahraich, Banda Barabanki, Bareilly, Bijnor, Chandauli, Fatehpur, Gorakhpur, Hamirpur, Lakhimpur Kheri, Lalitpur, Pilibhit, Pratapgarh, Rampur, Saharanpur and Sonbhadra cities of Uttar Pradesh. Mainly four types of species cultivated by NBM are Bambusa balcoa, Bambusa nutans, Bambusa bambos, Dendrocalamus hamiltonii.

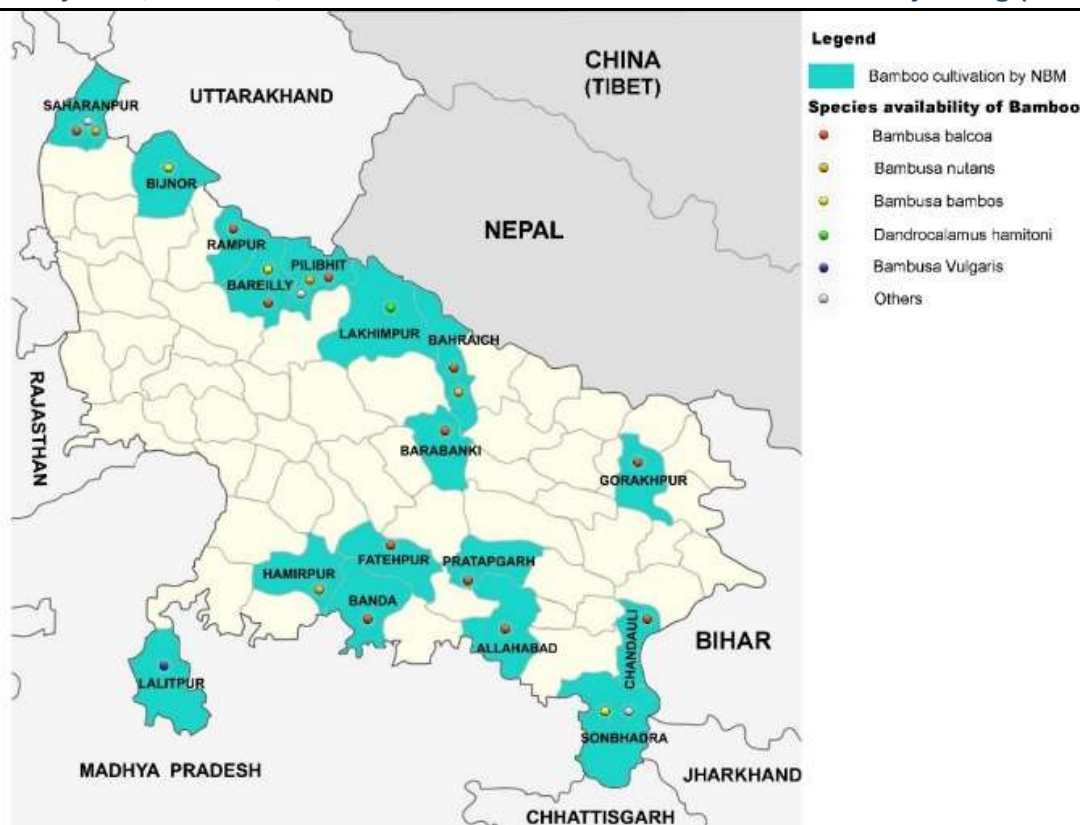


Figure 1 Cultivation of bamboos in Uttar Pradesh by NBM (Author)

4.2. Properties and uses of bamboo species

There are majorly four types of species plantations done by NBM. These species are the *Bambusa balcoa*, *Bambusa nutans*, *Bambusa bambos*, and *Dendrocalamus hamiltonii*. There are properties and uses of these species.

Table 1 Mechanical Properties of different species

Bamboo species	Height	Dia	Elastic Modulus (N/mm ²)	Compressive strength (N/mm ²)	Tensile strength (N/mm ²)	Shear strength (N/mm ²)	Bending Strength (N/mm ²)
<i>Bambusa balcoa</i>	16-25 m	7 -15 cm	11118	56	164	11.9	102
<i>Bambusa nutans</i>	6-15 m	5-10 cm	12068	60	208	10.5	116
<i>Bambusa bambos</i>	20-30 m	10- 18 cm	8533	54	121	9.9	90
<i>Dendrocalamus hamiltonii</i>	12-25m	10-19 cm	9629	70	177	6.7	89

(Stephane 2016)

Mainly four types of bamboo cultivated by NBM. Also, can be used for construction. Bamboo has an elastic modulus between 8533 to 12068 N/mm², compressive strength between 54 to 70 N/mm², Tensile strength between 121 to 208 N/mm², shear strength between 6.7 to 11.9 N/mm², and bending strength between 89 to 116 N/mm².

5. MARKET SURVEY

Market survey of Lucknow Bansmandi to analysed the cost, availability, transportation and uses of bamboo. So, according to the market survey,

5.1. Cost of Bamboo

The Cost of Bamboo is **75 to 110 Rs/pecks** and the quality is not good according to the local contractor of bamboo in Lucknow. The Costs of bamboo depend on the width of bamboo if bamboo has maximum width the cost would be maximum.

5.2. Causes of Degradation

There are two causes of the Degradation of Bamboo.

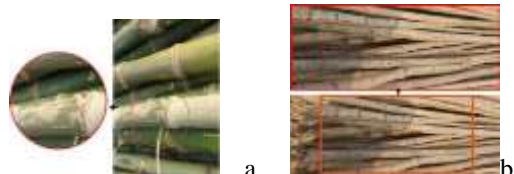


Figure 2 a. Insects and fungi attack b. Cracks/splits (Primary)

5.2.1. Insects and fungi attack: They attack due to the bamboo horizontally being stored on mud and it has direct contact with mud.

5.2.2. Cracks/splits: Cracks happen due to the dryness because of heat.

5.3. Treatment of Bamboo

There was no treatment.

5.4. Life Span of Bamboo

The Life span of bamboo is 1 to 2 years.

5.5. Availability of Bamboo

Transportation of bamboo

From Local in Uttar Pradesh- Sitapur, Unnao and Faizabad.

From Another State: Assam

5.6. Sizes of Bamboo

Length: 12ft, 16ft, 18ft, 24ft and 28ft

Dia: 2inch to 4inch

5.7. Uses of bamboo in Lucknow

Bamboo is used for traditional houses, checha (boundary wall), stairs, stools etc.

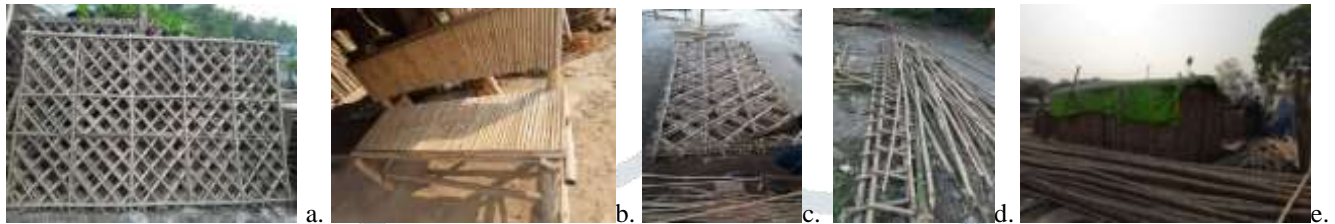


Figure 3 a. Checha (Bamboo wall) b. Bamboo stool c. Boundary wall d. stair e. Traditional Bamboo house (source: Primary)

5.8. Inferences: Bamboo is a cost-effective material but without the treatment its life span is low. It is used as external and internal building material.

6. CASE STUDIES

6.1. Live Study: Theth Banarasi Bati Chokha Restaurant, Varanasi

Location: Assi Ghat, Nagwa Road, Varanasi

Climate Type: Composite

Building Type: Restaurant

Architecture Type: Traditional + Modern

Site Area: 3200 sqft

Building shape: Rectangle

Construction Materials: Bamboo, Timber, Mud and RCC foundation.

6.1.1. Building Plan

Building in a rectangle shape and divided into three parts are administration area, indoor sitting and outdoor sitting. The length is 80 ft., width 40 ft. and the area of a restaurant is 3200 sqft. The Backside is facing Ghats and rivers. The Administration area is the kitchen, store and Reception. Outdoor space is the general sitting space but Indoor spaces are divided into parts according to the eastern city of Uttar Pradesh and that space shows the culture of that city. A bamboo arch made in the backside and a well in the front side of the restaurant.



Figure 4 Plan and Views of Restaurant (primary)

6.1.2. Building Material

Building material is Arundinaria species (nearly available) bamboo that comes from the Chandauli district of Uttar Pradesh and supportive materials are mud, timber, terracotta roof tile, and RCC foundation.



Figure 5 Building material (primary)

6.1.3. Treatment/ Maintenance

To preserve the bamboo, they use wooden paint. Yearly maintenance is required for the bamboo structures.

6.1.4. Joinery details of the Bamboo structure

6.1.4.1. Foundation

RCC foundation is used to support the bamboo structure.

6.1.4.2. Column to Beam Joint

Separate bamboo column joint with separate beam to support the roof.

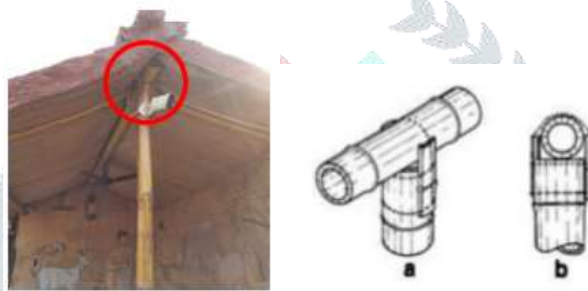


Figure 6 Column to Beam joint (primary)

6.1.4.3. Beam to Beam Joint

Separate bamboo beam joint with a separate bamboo beam.



Figure 7 Beam to Beam joint (primary)

6.1.4.4. Wall Joinery

Bamboo split wall painted by wooden paint and no wooden plaster on a wall.

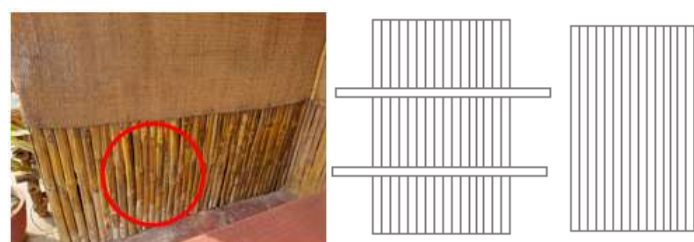


Figure 8 Wall joint (primary)

6.2. Literature Study: Mising Tribe, Assam

Location: Assam

Climate Type: Cold Climate

Building Type: Residence (Community)

Architecture Type: Vernacular

Building shape: Rectangle

Construction Materials: Bamboo, wood, cane, reed, thatch.

6.2.1. Building plan

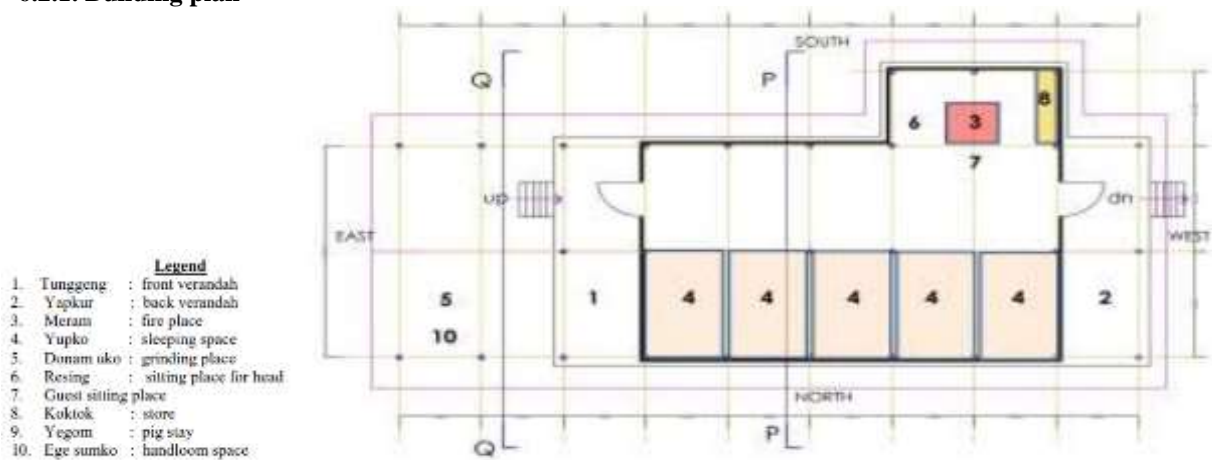


Figure 9 Plan (Barman et al. 2020)



Figure 10 Space for headman, koktok, meram and rapte for Apong (Barman et al. 2020)

The house on stilts is a big hall with an open kitchen for a large joint family. Places around the fireplace act as a family interactive space. The fireplace keeps the house warm during winter. The animals living under the stilt floor also get warmer living space. The main entrance to the house is from the east side, Sleeping areas on the Northside. The main architectural feature of the house is the double-height front portico which is used for grinding & handloom space. The stilt platform is 5 to 7 feet high to accommodate handloom and pig stay under it. The houses have perforated flooring that allows for bottom-up ventilation. These homes were built on stilts to protect residents from wild animals, particularly elephants. (Barman et al. 2020)

6.2.2. Building Material

Bamboo species uses by missing tribe is Bambusa balcoa and materials to support bamboo structure are wood, cane, reed, thatch. (Barman et al. 2020)

6.2.3. Treatment/ Maintenance

Yearly maintenance is required.

6.2.4. Joinery details of the Bamboo structure

6.2.4.1. Foundation



Figure 11 Stilt floor (Barman et al. 2020)

Majuli district is its flood-prone area so, people construct stilt floor planning.

6.2.4.2. Column to Beam Joint



Figure 12 Column to beam joint (Barman et al. 2020)

Separate bamboo column joint with separate beam to support the roof.

6.2.4.3. Beam to Beam Joint



Figure 13 Beam to Beam joint (Barman et al. 2020)

Separate bamboo beam joint with the separate bamboo beam.

6.2.4.4. Wall Joinery



Figure 14 Wall joint (Barman et al. 2020)

Bamboo split wall without uses of any covering material like plaster.

6.3. Literature Study: Green School, Indonesia

Location: Bali, Indonesia

Climate Type: Tropical Climate

Building Type: Educational

Total site area: 103,142.63 sqm

Ground floor area: 5,534 sqm

Built up Area: 7542 sqm

Architecture Type: Modern

Building shape: Organic shape

Construction Materials: Bamboo, and Timber

6.3.1. Building Plan

The school was created utilizing an organic permaculture system and was designed to respond to the soil ecology perfectly.



Figure 18 Site Plan

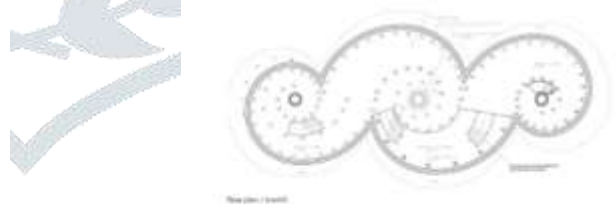


Figure 17 Ground floor plan (Karsono et al., n.d.)

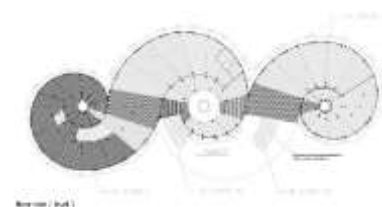


Figure 16 First floor plan (Karsono et al., n.d.)

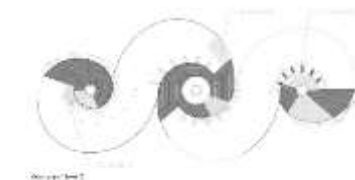


Figure 15 Second floor plan (Karsono et al., n.d.)

6.3.2. Building Material

Bamboo species uses in Green School, Bali is *Dandrocalamus asper* and the material to support bamboo structure is timber. All of the structures in the school complex were designed to foster a culture of environmental stewardship via the use of organic materials and renewable energy sources such as micro hydropower, solar electricity, and bio-diesel. Each building, on the other hand, was created by a team of electrical engineers, designers, and bamboo craftsmen in Bali, rather than by an architect. (Hazzard, Hazzard, and Erickson, n.d.)

6.3.3. Treatment/ Maintenance

At the Green School, every structural bamboo is treated extensively with an organic Borax chemical. To guarantee insect resistance, the bamboo is cleansed and then immersed in a Borax bath for 4-6 weeks. To avoid moisture infiltration, the bamboo members are coated with an environmentally friendly waterproof coating. (Hazzard, Hazzard, and Erickson, n.d.)



Figure 19 a. Washing b. Treating & Drying c. Processing bamboo (Hazzard, Hazzard, and Erickson, n.d.)

6.3.4. Joinery details of the Bamboo structure

6.3.4.1. Foundation



Figure 20 Stilt floor planning (Hazzard, Hazzard, and Erickson, n.d.)

Stilt floor planning with bamboo.

6.3.4.2. Column to Beam Joint



Figure 21 Column to beam joint (Hazzard, Hazzard, and Erickson, n.d.)

Separate bamboo column joint with separate beam to support the roof.

6.3.4.3. Beam to Beam Joint

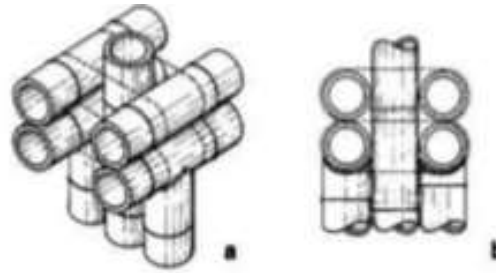


Figure 22 Beam to Beam joint (Hazzard, Hazzard, and Erickson, n.d.)

Two-sided double bamboo beam joint with the double bamboo beam to provide good strength to a building.

6.3.4.4. Wall Joinery

There is no wall construction and the boundary wall are a split wall.

6.4. Comparative Analysis of Case Study

This table determines the comparative analysis of the case studies.

Table 2 the Comparative Analysis of Case Studies

Parameters	Theth banarasi Baati Chokha, Varanasi	Mising Tribe houses, Assam	Green School, Bali
Location	Varanasi, Uttar Pradesh	Majuli, Assam	Bali, Indonesia
Climate	Composite	Cold	Tropical
Architecture type	Traditional & modern	Vernacular	Modern
Building shape	Rectangle	Rectangle	Organic
Bamboo Species	Arundinaria	Bambusa balcoa	Dandrocalamus asper
Supportive materials	Timber, Mud and RCC foundation	Wood, cane, reed, thatch	Timber
Treatment/ maintenance	Yearly with a wooden paint	-	Cleansed and then immersed in a Borax bath for 4-6 weeks.
Foundation type	RCC	Stilt Floor	Stilt Floor
Beam to column joint	Separate bamboo joinery	Separate bamboo joinery	Separate bamboo joinery
Beam to Beam joint	Separate bamboo joinery	Separate bamboo joinery	Multiple bamboo joinery
Wall join	Split Wall	Split Wall	No wall in the building and the boundary wall is a split wall

(Author)

Inferences: Bamboo is a versatile organic material that can use in every type of climate. it can convert into many shapes with multiple joineries.

7. COST ANALYSIS

We are taking a small house (Area: 28ft * 16ft) in Uttar Pradesh for a cost-comparison of building structure. In the first case, we considered house constructs with conventional material and in the second case house construct with bamboo.

7.1. First Case: House Construct with Conventional Material

We considered a house with an area of 28ft * 16ft in Uttar Pradesh and that house construct with conventional materials. The Height of the building is 10ft. It is the details of the column. There are two types: 9" * 9" column and 9" * 12" column.

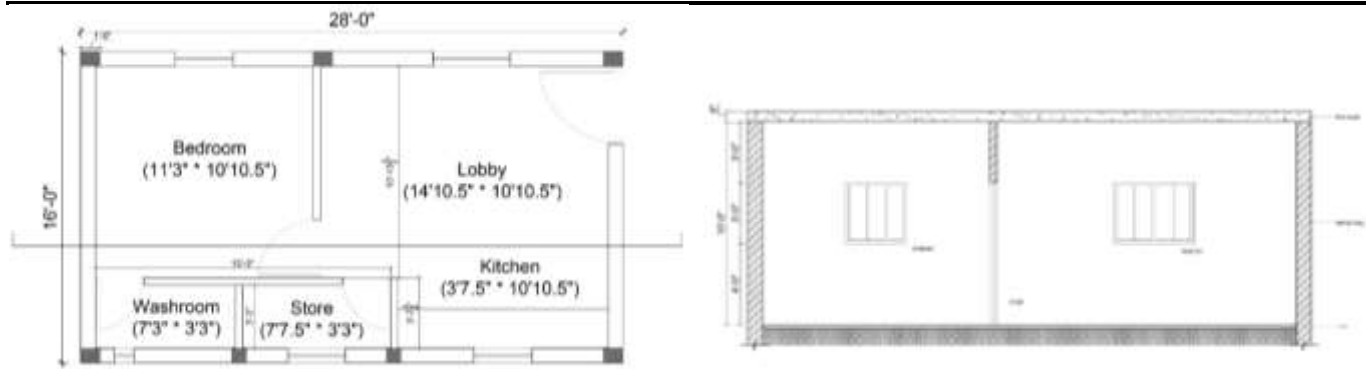


Figure 23 Conventional building plan and section

7.2. Second Case: House Construct with Bamboo

We considered a house with a same area (28ft * 16ft) as conventional building in Uttar Pradesh and that house construct with bamboo.

Width of bamboo house wall is depending on the width of bamboo. So here we considered 6-inch bamboo wall used for construction. Height of bamboo house is 10 ft. 13 columns used for this house and 2 bamboos used for each column.



Figure 24 Plan and section of Bamboo house (Author)

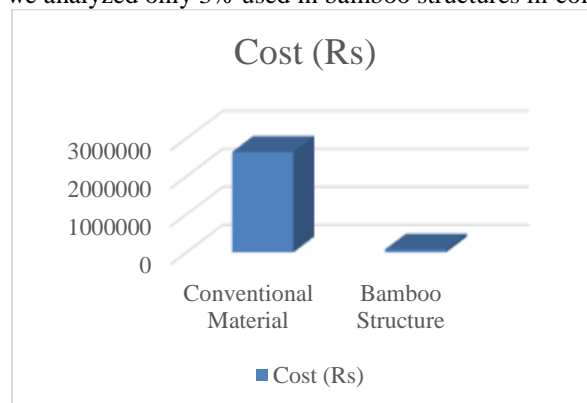
7.3. Cost Comparisons

COST ANALYSIS OF SMALL HOUSE
UTTAR PRADESH
SUMMARY OF BoQ

Cost for Convetinal structure					
Ref no:					DATE : 27/01/2022
S.No	Description	Quantity	Unit	Rate (Rs)	Cost (Rs)
1.00	Excavation for Foundation (9" *12")	162.60	cu-ft	10.700	1739.82
2.00	PCC at Foundation	30.00	sq-ft	736.515	22095.45
3.00	Footing Rectange portaion	18.75	sq-ft	30.795	577.41
4.00	Column 1 (9" *12")	61.58	cu-ft	1063.380	65482.94
5.00	Excavation for Foundation (9" *9")	43.36	cu-ft	10.700	463.95
6.00	PCC at Foundation	8.00	sq-ft	736.515	5892.12
7.00	Footing Rectange portaion	4.50	sq-ft	30.795	138.58
8.00	Column 2 (9" *9")	1847.00	cu-ft	1063.380	1964062.86
9.00	Earth filing in plinth	1985.41	cu-ft	68.165	135335.47
10.00	Actual Brick work 9"	747.00	sq-ft	108.000	80676.00
11.00	Actual Brick work 4.5"	164.35	sq-ft	64.000	10518.40
12.00	Slab Concrete	448.00	sq-ft	800.000	358400.00
	TOTAL COST				2645382.999
Cost for Bamboo structure					
Ref no:					DATE : 27/01/2022
S.No	Description	Quantity	Unit	Rate (Rs)	Cost (Rs)
a	Bamboo Rate	1.00	sq-ft	4.22	
b	Bamboo Treatment				
i	Boric Acid	1.00	sq-ft	10.00	
ii	Borax	1.00	sq-ft	30.00	
1.00	Total Rate		sq-ft	44.22	
2.00	Treatment Bamboo for Column	26.00	pcs	276.00	7176.00
3.00	Bamboo Wall	976.00	sq-ft	44.22	43158.72
4.00	Bamboo Slab	448.00	sq-ft	60.00	26880.00
	TOTAL COST				77214.72

Figure 25 Cost Comparison (Author)

So. After the comparison of cost, we analyzed only 3% used in bamboo structures in comparison to conventional buildings.



Bar Chart 1 Cost Comparison

8. CONCLUSION

Bamboo is a locally available sustainable material and uses in many forms and shapes. In Uttar Pradesh, only 0.54% of availability but the national bamboo mission cultivated good quality species types (*Bambusa balcoa*, *Bambusa nutans*, *Bambusa bambos* and *Dendrocalamus hamiltonii*) to promote the bamboo. NBM cultivated bamboo in Allahabad, Bahraich, Banda Barabanki, Bareilly, Bijnor, Chandauli, Fatehpur, Gorakhpur, Hamirpur, Lakhimpur Kheri, Lalitpur, Pilibhit, Pratapgarh, Rampur, Saharanpur and Sonbhadra cities of Uttar Pradesh. It is cost-effective material and can use as an alternative material. After the comparison of cost, we analysed only 3% used in bamboo structures in comparison to conventional buildings. It is cost-effective material and can use as an alternative material.

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