

Sustainable Construction Materials for Bangladesh in Tropical C-Limate, Literature Review

Apu Hrishi*

Architect, UK

Abstract: Bamboo is one of the most significant materials in Bangladesh which can play a vital role in the construction sector. It is a natural device, unique, strong, and long-lasting, as well as variously used in every circle of life. Nowadays, it is becoming an attractive and fashionable material throughout the world. Most architects all over the world are using bamboo as a construction material in modern design and techniques.

Bamboo is most commonly used in construction for walls, partitions, roofs, and main elements such as posts, beams, and structural frameworks with a range of traditional and modern connections, among other things. However, there are almost no suggestions for using bamboo in this case.

The objective of this investigation is to outline crucial instructions for using bamboo, which is not prominently mentioned. There were a total of 18 articles examined and analyzed for this paper.

Keywords: Bangladesh, Bamboo, Structure, Materials, Joints.

1. INTRODUCTION

In Bangladesh as well as the rest of the globe, bamboo is the most popular low-cost material. It is commonly utilized in one region of Bangladesh in our nation. The fact that bamboo planting in Bangladesh is directly tied to rural housing is the most important factor. The walls, columns, and roofs in rural areas are made of bamboo. Due to the fact that most people in rural areas are poor, they have always thought of inexpensive and affordable building materials.

The majority of the time, especially in countries where it is efficient, poor people use bamboo, a widely used local building material. In India and China, bamboo is referred to as "the poor man's wood" and is dubbed "the poor man's friend" in these countries. It is one of the most frequently used building materials in low-tech, locally produced, low-cost housing (Andra and Larionescu, n.d.).

In our building industry, bamboo is now taking on a more significant role. It is used in a variety of applications, including as a material for partition walls, roofs, and main structures, as well as innovative modern techniques and a variety of traditional bamboo joints, shelters, fences, bridges, fish pens, water pipelines, domestic usage, as a raw material for household utensils, etc.

Furthermore, because they are affordable, widely accessible, and ecologically friendly, the majority of architects in our nation are captivated by these

sustainable materials. They offer Bangladesh's architectural scene an entirely new viewpoint and widen the range of options for using these materials.

The proper direction for this building, which is not stated, is the most important factor behind the bamboo construction, nevertheless. It is quite important or this platform in this regard.

2. LITERATURE REVIEW

2.1. Bamboo

In the tropics and subtropics, bamboo is an important bio resource. It is important in other areas of the world as well (the temperate zone). Bamboos are primarily found in climates that are tropical or subtropical as well as in the tropical monsoon zone. With around 1,500 species, bamboos are divided into 75 genera (Rahman *et al.*, 2018).

The bambusoideae subfamily of the Poaceae family includes it. On the earth, there are over 1250 distinct species. These species can be found thriving in humid-tropical, subtropical, and temperate climates in Asia, Africa, Latin America, Australia, New Zealand, and the Pacific Ocean, where temperatures range from -28°C to 50°C and altitudes range from sea level to 4000 m (Himalayas). They can also be found in the jungle, on mountain slopes, on farms, and on plantations. A tree cannot match the oxygen production of bamboo per square meter (Andra and Larionescu, n.d.).

14 million hectares are covered with bamboo forests worldwide, with the bulk of these zones being in Asia, the Pacific, the Americas, and Africa. The world's

*Address correspondence to this author at the Architect, UK;
E-mail: arabindu01@gmail.com

greatest bamboo forests, however, with around 80% of all species, are found in East Asia and Southeast Asia (Rahman *et al.*, 2018).

Additionally, bamboos play a significant role in regional economies all around the world, but Asia is where they are most prevalent. According to estimates, \$7 billion worth of bamboo products are used or consumed annually by 2.5 billion people. Construction of houses, tools, musical instruments, and other handicrafts has long been done using bamboo. Recently developed technologies have made bamboos essential in the global market as paper pulp, parquet, ply bamboo, and canned vegetables (Bystriakova *et al.*, 2003).

Despite bamboos' current importance in the economy, society, and ecology, there aren't many statistics on where they are found or how readily available they are, particularly in unmanaged forests. Due to the limited naming and classification systems for bamboo, as well as the lack of appropriate documentation of species characteristics, it is difficult to gather accurate data on species and their distribution patterns.

As a result, estimations of the bamboo resource base are rarely complete, clear, or in depth in practically all Asian nations. A thorough understanding of the distribution and status of a wide variety of forest bamboo species is required in order to expand bamboo diversity conservation to additional species. These calls for making good use of the resources that are available.

2.2. Bamboo as a Construction Material

In tropical and subtropical regions all throughout the world, bamboo has a long history of use as a building material. It is often used in many different construction projects, especially in rural residences (Ripublication.com, 2010). Bamboo is a versatile material because of its superior strength-to-weight ratio, use, and availability. Bamboo requires chemical treatment due to its low natural durability. It can be used for foundations, doors, windows, walls, ceilings, bamboo trusses, purlins, rafters, and reapers on the roof in addition to flooring, scaffolding, manhole covers, windows, and doors (Das & Sarkar, 2018).

A sustainable and kind to the environment resource is bamboo. The forest cover on our world is currently vanishing. It's astonishing how much woodland has been lost. 95 million trees worldwide are gone forever

each year. This process can be stopped by using bamboo as a building material. The greatest growth rate for bamboo is 1200 mm per day. In 3-5 years, bamboo is entirely suitable for construction (Lapina and Zakieva, 2021)

Of the 1,200 species, only around 20 are thought to be suitable for building. The three most renowned of these are *Dendrocalamus asper*, *Guadua*, and *Moso bamboo (Phyllostachys edulis)*, among others. Giants by any standard, these bamboo varieties. The diameter and height of their culms are 10 to 18 cm and 12 to 20 meters, respectively. As a result of the ecology of the development area, these traits differ per species (Escamilla and Habert, 2014).

Bamboo has been used as a building material for a very long time, but because it isn't preserved, treated, or kept up with, it is getting harder and harder to use in buildings. In Bangladesh, bamboo scaffolding has been replaced with metal pipe in the construction of new buildings. Despite this, brick and concrete are now more popular than bamboo, which was historically commonly used in rural regions.

2.3. Construction Methods of Bamboo

A lengthy and illustrious history of hundreds of years has been spent using bamboo in construction. In this material, various cultures have found a cost-effective construction method that provides sound, light, and easily adaptable shelter. Even the least experienced person can participate thanks to the often-used easy and clear methods, activities, and tools. Despite human exploitation and abuse, trees nevertheless play a vital role in the survival of humanity. Nature's unending gift to man has benefited him for a long time (Ripublication.com, 2010). It's difficult to imagine a plant like bamboo being used as a building material in the cutting-edge world of materials and technologies we live in today. But it was all absolutely pointless. In China, Oceania, Latin America, South America, and Central and South Africa, bamboo is frequently utilized as a building material. It is used to build the roof, scaffolding, and finishing materials in addition to the house's basic construction (walls and columns) (Lapina and Zakieva, 2021).

This article provides several bamboo construction techniques.

2.3.1. Foundation

Despite having a short lifespan, bamboos are frequently used as the foundation or pillars supporting

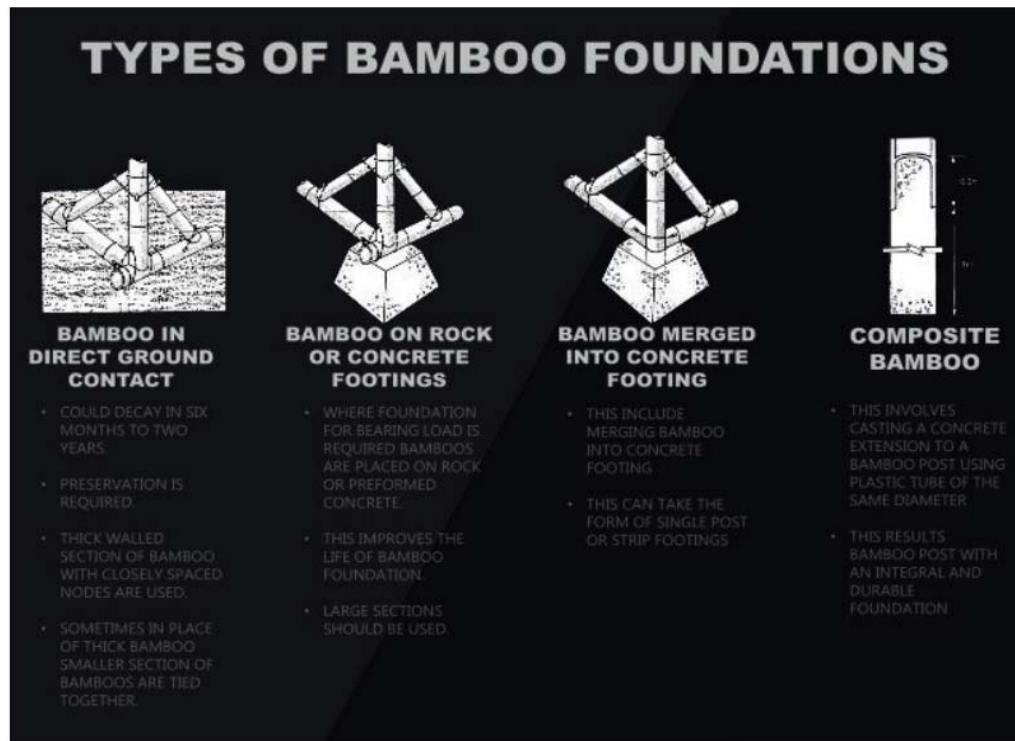


Figure 1: Types of foundations.

structures built on elevated platforms. There are many different sizes and styles of bamboo foundations (Ripublication.com, 2010).

The following are the identified bamboo foundations:

2.3.2. Flooring

If the flooring is at ground level, it can be made entirely out of compacted earth, with or without a bamboo matting covering. The preferred way is to raise the floor above the ground in order to create a floating structure. In addition to providing a covered storage place close to the floor, this aids in keeping the area tidy. The surface of an earth floor can be made more stable by laying down rough bamboo boards created by splitting and flattening complete culms (Ripublication.com, 2010).

The following are the numerous types that are used:

- Small bamboo culms
- Split bamboo
- Flattened bamboo
- Bamboo mats
- Bamboo plastic composites

2.3.3. Walls

A lot of bamboo is utilized to construct partitions and walls. The main structural components are posts and beams. They must withstand the structure's weight as well as pressure from the environment and people. It contributes to the structure's overall stability despite being susceptible to horizontal stresses (Ripublication.com, 2010).

2.3.4. Roofing

Due to its strength, durability, and lightweight, bamboo is an excellent roofing material. Bamboo roof structures with purlins, rafters, and trusses can also be made of the material. The canopy is protected from the wind, rain, and sun by the roof, which also provides shade and a clear, usable space beneath it (Ripublication.com, 2010).

It has also suggested bamboo shingles and tiles. Bamboo shingles are manufactured from mature bamboo canes with a 30° minimum pitch and a 3-4 cm width. The shingles are secured to the 4 cm wide bamboo battens as well as the tiles, and the roof has a minimum slope of 30 degrees. Cut a 30 cm long culm with a 13 cm diameter. The diaphragm is used to make a nib to bind the tile to the batten (Andra and Larionescu, n.d.).

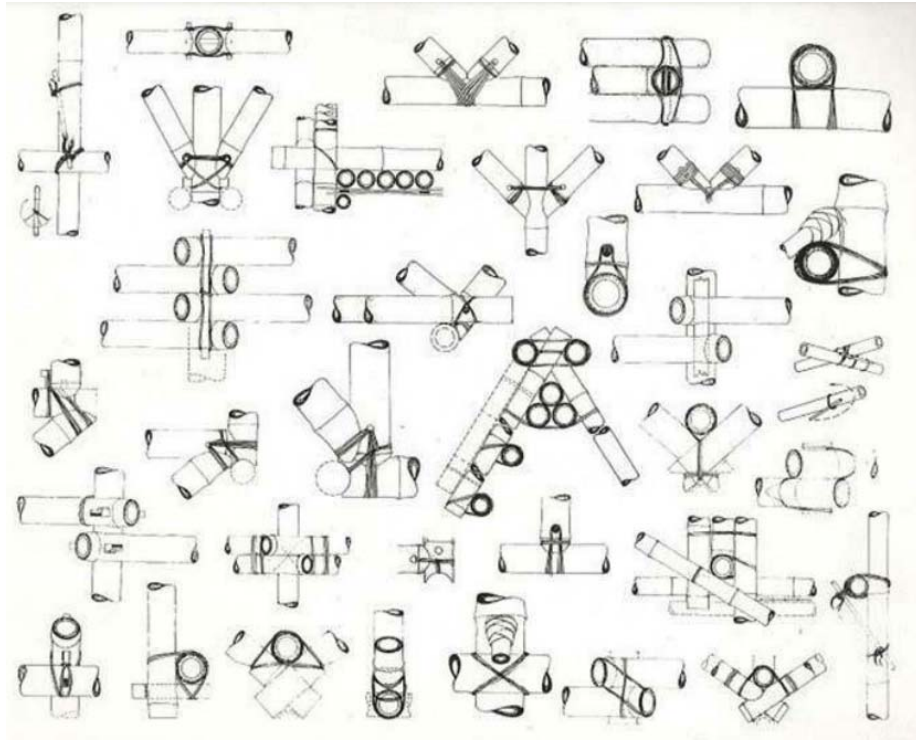


Figure 2: Types of connections.

2.3.5. Scaffolding

Bamboo may be utilized to produce safe scaffolding even for very tall buildings because of the positive relationship between load-bearing capacity and weight. Only the lashing joint is used. The cane extension is performed by tying the ends of the cane together with many ties. This approach has the significant benefit of allowing the joints to be swiftly re-tensioned to the proper degree and then released (Ripublication.com, 2010).

The use of bamboo guidelines is a significant issue that has persisted despite the fact that multiple authors have provided bamboo construction methods in various ways. There is no intricate framework in the bamboo. It's crucial on this platform to operate without rules.

3. BAMBOO JOINTS & CONNECTIONS

Bamboo is a classic building material with a long history of use that needs a precise connecting mechanism during construction that includes two components: friction-tight lashing and mortise-tenon (Lao, 2021).

Friction-tight lashing: Natural materials such as sisal, coconut, rattan, and palm fibers are used in lashing, a very notable type of bamboo connection. Dried bamboo strips are also utilized as lashing rope in

rural regions due to their flexibility, simplicity, and low cost (Lao, 2021).

Mortise-tenon joint: Mortise-tenon is a semi-rigid connection that binds the structure member without the use of a nail or bolt, and it is one of the most extensively used historical connectors in timber buildings. The two most frequent mortise-tenon joints are straight tenon and regular. The tenon-end beam can be put into the notch on a column to establish a unique connection system since the beam end is built as a tenon and a mortise is made on the column (Lao, 2021).

The most common connections between structural nodes are indicated (Lapina and Zakieva,2021).

Designers and researchers have used metal, concrete, and PVC to improve joint stiffness in recent years based on established information and previous experiences (Lao, 2021). Bamboo can be linked in a number of different ways. In the past, the most preferred approach was to bind using natural fiber and bamboo pins. By pioneering the use of steel bolts and concrete, Simon Velez and Marcelo Villegas revolutionized bamboo structure construction in the 20th century. As part of the workshops, we attempted a few different connection details, which are explained below (Vahanvati, n.d.).

A. Lashing and pinning



Figure 3: Lashing & pinning.

B. Steel bolt



Figure 4: Steel bolt.

C. Clamps



Figure 5: Clamps.

C. Hubs



Figure 6: Hubs.

D. Brackets and plates



Figure 7: Brackets & plates (Vahanvati, n.d.).



Figure 8: Bamboo clamp connector (Vahanvati, n.d.).

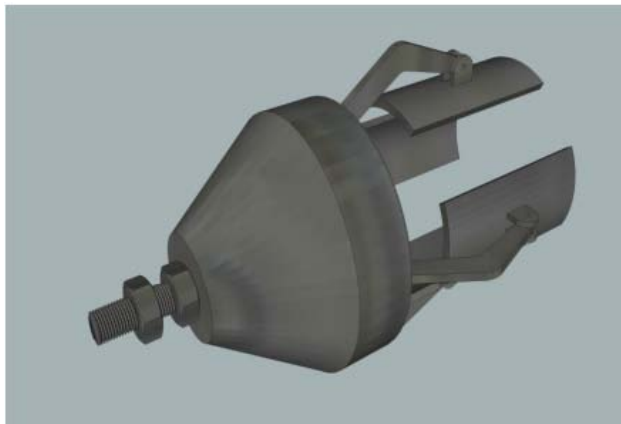


Figure 9: Clamp.



Figure 10: Ring.



Figure 11: Circular disc.

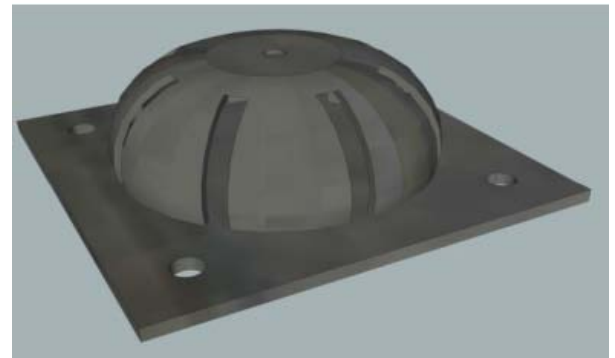


Figure 12: Footing plate.

There are a few different connection details pictures further:

The Bamboo Clamp Connector

The Bamboo Clamp Connector was designed to make the bamboo building more efficient. It combines the best characteristics of the various types of connections outlined previously. The connector is designed for little to medium-sized constructions (Vahanvati, n.d.).

Design Opportunities

There are some design opportunities regarding the bamboo Clamp Connector:

Different authors defined the joints and connections in great detail and provided several examples, but they were unable to explain the bamboo structure's guidelines, rules, and regulations. Bamboo is a popular sustainable material among architects all over the world. We have adequate principles in concrete

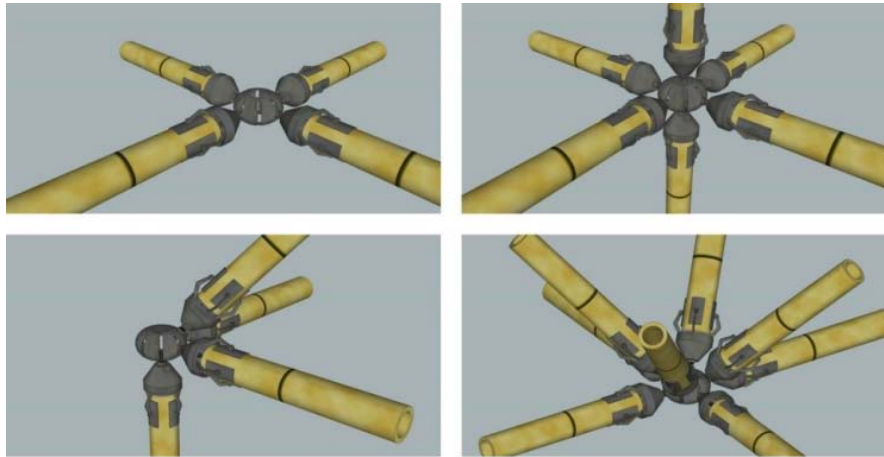


Figure 13: Bamboo Clamp Connector.



Figure 14: Bamboo Clamp Connector.

construction, as a result of which it is able to fully understand the construction industry. However, there are several disadvantages to bamboo construction. However, with the right criteria in place, the bias of bamboo construction might readily be increased.

4. RESULTS & MATRIX

A total of 18 research papers were collected (Appendix 1), and some fundamental topics were identified in these papers. The number of paper that discusses each topic reflects the research interest in these topics. In general, the reviewed articles can be categorized with their various focus into two groups.

One group illustrates bamboo's advantages and disadvantages, bamboo techniques modern & traditional, joints, bamboo as a low-cost construction material, structure, etc. Similarly, the other group also discussed bamboo's mechanical properties, bamboo conservation, and bamboo ecological impact.

The results reveal that bamboo has been a very popular research topic, however, there has been very limited discussion clarifying the guidelines for using bamboo. Moreover, bamboo is an important element for construction and low-cost materials throughout the world which has not been studied thoroughly its very essential for our construction platform.

APPENDIX 1

A matrix of literature & relevant themes													
Researchers	Aim	Methodology					Key findings	Research Themes /ideas					
		modeling	Case studies	Interviews	questionnaires	experimental		Low-income	Thermal comfort	Costs	Financial viability	Energy efficiency	Social-cultural
01. Vahnavali, (2015)	Bamboo use, particularly as a structural material, and bamboo connecting methods					✓	Traditional, affordable, and recommended uses for bamboo.			✓			
02. Sharma, Dhanwanthi, and Mehta (2014)	Bamboo is used in construction for posts, beams, key elements, walls, partitions, and other components that typically make up the structural framework. Its benefits and drawbacks are also discussed.					✓	Bamboo use recommendation	✓		✓			✓
03. Rahman et al., (2017)	Preserving the species of bamboo.					✓	Bamboo is maintained for and protected.						✓
04 M et al.,(2018)	Eco-effects of bamboo				✓		Insufficient knowledge of biodiversity and its potential impact on the ecosystem.						✓
05. Lapina and Zakieva (2021)	Building and architectural uses for bamboo Construction of complex architectural forms is possible with bamboo.		✓				Guidelines for using bamboo; low cost; modern approaches and procedures.			✓			✓
06. Maurina, (2019)	Structure of bamboo, connections, joint information, and definition of incorrect and proper connections with a figure and an example.		✓				Unavailability of information on current procedures and techniques and bamboo usage guidelines.			✓			
07. Morán et al., (2016)	Various joints, connectors, and other components are discussed.					✓	Guidelines for using bamboo & lack of additional joints illustrated.			✓			
08. Lao,(2021)	Discuss some of the more contemporary joints as well as the classic bamboo connectors.		✓			✓	Recommendations for using bamboo in construction, lack of joints.			✓			
09. Platt (2019)	Standardization, public approval, and vernacular architecture are						Guidelines for using bamboo,						

	all topics that are debated when bamboo is used as a building material.		✓				lack of construction techniques & joints.		✓					✓
10. Sharma et al., (2015)	It was explored how to incorporate wood and wood-based materials into structural designs.					✓	Discussing rules while lacking joints.			✓				
11. Das and Sarkar(2018)	Bamboo is used in construction for things like walls, partitions, and structural frameworks. This usage also includes bamboo's benefits and drawbacks.		✓				There are no commonly recognized arguments, construction techniques, or bamboo usage recommendations.	✓		✓				
12. Yadav and Mathur(2021)	Use of bamboo as a construction material and advantages & disadvantages of bamboo		✓				Lack of joint discussion, construction methods,& guidelines for using bamboo.	✓	✓	✓			✓	✓
13. Mohan et al., (2022)	Use of bamboo construction, preservation, techniques & sustainability, etc.		✓				Lack of joint details, techniques construction methods,& guidelines for using bamboo			✓			✓	✓
14. Lianto et al., (2019)	Use of bamboo in the construction sector such as beams, columns, walls, and roofs as well as changing the face of modern architecture, bamboo, earthquake, etc.		✓				Not sufficient information about the bamboo joint details, techniques, methods and also guidelines, etc.		✓	✓				
15. Escamilla and Haberl (2014)	This study focus on calculating the environmental impact of producing and using construction materials made of bamboo.		✓				Lack of information about bamboo-based construction materials and environmental impact etc.			✓			✓	
16. Fahim. et al., (2022)	Discussion about the bamboo treatment, preservation, mechanical properties, bamboo standard codes, fiber, etc.					✓	There is still much to be implemented in terms of construction industry standards and specifications, guidelines, as well as finding methods for creating strong connections between bamboo reinforcement in concrete.			✓				
17. Pawar (2014)	Utilization of bamboo, and its ecological benefits						Bamboo joints & guidelines for using bamboo		✓		✓		✓	
18. Mohan et al., (2022)	The project aims to improve knowledge of bamboo's use as an environmentally friendly building material.		✓	✓			Lack of construction techniques & methods.			✓				✓
Present study	Guideline for using bamboo in construction		✓			✓		✓		✓				✓

5. CONCLUSION

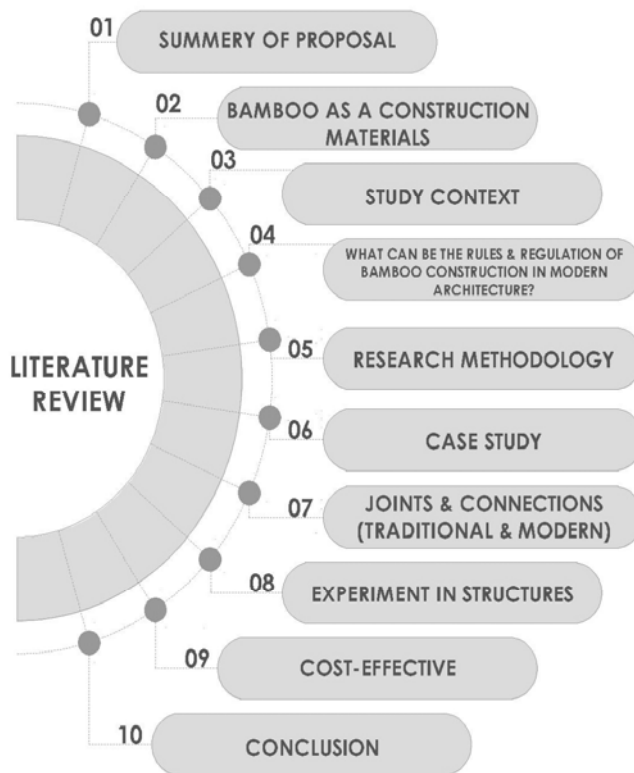
The purpose of this literature research was to obtain a better understanding of bamboo construction and how the material is now used in modern architecture as a construction material. No particular guidelines are used for bamboo construction which is very important for this construction. However, the construction industry is currently growing at a rapid rate in this world, making bamboo construction very difficult without certain regulations. A proper guideline can make this material more cost-effective and easier to construct.

6. RESEARCH QUESTION

How much and how cost-effective will bamboo architecture contribute to modern life in the future?

What can be the rules and regulations of bamboo construction in modern architecture?

7. METHODOLOGY



ACKNOWLEDGEMENTS

The following is a literature review that was written for MSc academic objectives, as well as The De Montfort University faculty member who assisted with this research is gratefully acknowledged by the article's writers.

REFERENCES

- Andra P, Larionescu J. (n.d.). 7 Bamboo in architecture and construction: properties, protection and processing. Available at: http://anale-arhitectura.spiruharet.ro/PDF/02_andra%20jacob%201.pdf. (17.11.2022)
- Andra P, Larionescu J. (n.d.). Bamboo in Architecture and Construction: Building with Bamboo. Available at: http://anale-arhitectura.spiruharet.ro/PDF/03_andra%20jacob%202.pdf (17.11.2022) Available at: <https://www.researchgate.net/publication/332351127>. (18.11.2022).
- Das A, Sarkar S. (2018). Importance of Bamboo in Building Construction. International Research Journal of Engineering and Technology (IRJET), 05(06), pp.1–4. Available at: <https://www.irjet.net/archives/V5/i6/IRJET-V5I682.pdf> (18.11.2022).
- International Bamboo and Rattan Organization. (2022). *Bamboo and Rattan for Inclusive and Green Development*. [online] Available at: <https://www.inbar.int/wpcontent/uploads/2020/05/1493099820.pdf>.
- Lao H. (2021). Connections for Bamboo Structures. In: IOP Conference Series: Earth and Environmental Science. 2nd International Conference on Geology, Mapping and Remote Sensing. The electrochemical society: IOP Publishing Ltd, pp.1–9. <https://doi.org/10.1088/1755-1315/783/1/012028>
- Lapina AP, Zakiyeva NI. (2021). Bamboo in modern construction and architecture. In: IOP Conference Series: Materials Science and Engineering. [online] International Scientific Conference 'Construction and Architecture: Theory and Practice of Innovative Development' (CATPID 2020). The electrochemical society: IOP Publishing Ltd, pp.1–7. <https://doi.org/10.1088/1757-899X/1083/1/012019>
- Maurina A. (2019). BAMBOO CONSTRUCTION. BAMBOO CONSTRUCTION, [online] n.d(n.d), pp.1–30. Available at: <https://www.researchgate.net/publication/342521292>.
- Pawar S. (2014). Bamboo in Construction Technology. [online] 4(4), pp.347–352. Available at: https://www.ripublication.com/aeee_spl/aeeev4n4spl_04.pdf.
- Pawar S. (2014). Bamboo in Construction Technology. 4(4), pp.347–352. Available at: https://www.ripublication.com/aeee_spl/aeeev4n4spl_04.pdf (17.11.2022)
- Rahman M, Parvin W, Sultana N, Tarek S. (2018). Conservation of bamboo species in a mini urban ecosystem of Bangladesh. Journal of Biodiversity Conservation and Bioresource Management, 3(2), pp.35–42. <https://doi.org/10.3329/jbcbm.v3i2.36026>
- Ripublication.com. (2010). IJECR, International Journal of Civil Engineering Research, Journal Publisher, Science Journal Publisher in India, Delhi, Indian Journals Subscription Agency, Indian Books Distributors, Mathematics Journals Publishers. Available at: <http://www.ripublication.com/ijcer.htm> (18.11.2022).
- Vahanvati M. (n.d.). The Challenge of connecting bamboo. Available at: <https://www.bamboo.org.au/wp-content/uploads/2017/04/WBC-2015-Paper-Munir-Vahanvati.pdf>. (18.11.2022).

FIGURE

Fig. 01, Pinterest. (n.d.). *Image result for bamboo connection in column | Bamboo, It cast, Connection*. [online] Available at: <https://www.pinterest.com.au/pin/575264552396781611/>. (20.07.2023)

Fig. 02, *Types of nodes% E2%80%99 connection - Google Search* (no date) *www.google.com*. Available at: <https://www.google.com/search?q=.+Types+of+nodes%E2%80%99+connection&tbn=isch&source=lnms&sa=X&ved=2ah>

UKEwj7IL7ZuciAAxVUFcAKHe0ECsQQ0pQJegQIDBAB&biw
=1536&bih=747&dpr=1.25#imgrc=WqklqfMyNXe4RM
(Accessed: 6 August 2023).

Fig. 3-14, Vahanvati, M. (n.d.). *The Challenge of connecting bamboo*. Available at: <https://www.bamboo.org.au/wp-content/uploads/2017/04/WBC-2015-Paper-Munir-Vahanvati.pdf>. (20.07.2023)

Received on 31-12-2023

Accepted on 10-01-2024

Published on 06-02-2024

<https://doi.org/10.6000/2817-2310.2024.03.03>

© 2024 Apu Hrishi; Licensee Lifescience Global.

This is an open-access article licensed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the work is properly cited.