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A New Paradigm in Using Bamboo as Sustainable Material for Future Building Construction

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Abstract

The 21st century is a modern era with the human egoism of world greed that results in the imbalance of the earth and the release of carbon gases on ozone that are very worrying. The 'Sustainable Development Goals' (SDG) by United Nation makes using sustainable materials such as bamboo for building construction. However, negative perception has made it a material that is not widely used. This study explores and observes the design transformations of bamboo building construction. As a result, the evolution of building shapes and building shapes has become more dynamic and unique.

Keywords: Sustainable, Material, Bamboo, Building

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1.0 Introduction

Nowadays, the world dramatically affects the destruction of the environment with the deterioration of the environment through depletion of resources such as quality of air, water, and soil; the destruction of ecosystems; habitat destruction; the extinction of wildlife, and pollution. It is defined as any change or disturbance to the environment perceived as deleterious or undesirable (Johnson, 1997). The rapid development of the world results in the imbalance of the earth's influence on the terrain and the emission of carbon gas on the ozone, which is the problem of unpredictable weather and the occurrence of floods, tornadoes, and widespread haze-wide.

Global temperature growth is also predicted to correlate with increased global precipitation. However, due to increased runoff, floods, augmented rates of soil erosion, and mass movement of land, a decline in water quality is probable, as while water will carry more nutrients, it will also carry more contaminants (Warner, 2010)

The United Nations International Strategy for Disaster Reduction defines environmental degradation as "the reduction of the capacity of the environment to meet social and ecological objectives and needs" (UNISDR, 2010) in the Sustainable Development Goals (SDG). Ecologically sustainable development is the environmental component of sustainable development. It can be achieved partially through the precautionary principle; if there are threats of serious or irreversible environmental damage, a lack of complete scientific certainty should not be used to postpone measures to prevent environmental degradation. For example, the construction industry has identified the negative environmental impact of using cement production (Ige et al., 2021). This has resulted in widespread interest in the need for

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green materials. The World Campaign SDG project has included the suggestions approach on the importance of preserving the earth by encouraging sustainable uses of natural resources like bamboo for construction purposes. The study aims to explore and observe the trend design transformations of bamboo building construction in Bali.

2.0 Literature Review

Bamboo is known as green gold and has been sustainable material for construction, and possesses excellent strength properties, especially tensile strength (Ahmad, 2001). Naturally, bamboo is a plant that grows worldwide, and more than 1500 species are distributed worldwide in tropical, equatorial, and semitropical climates. Through observation, bamboo grows in three distinct regions, patches on the edge of the riverbanks of human settlement and the forest area (Azmy et al., 1991). It is a fast-growing monocotyledon belonging to the Gramineae (family Bambusoideae), requires a short time to regrow, and is a widely available, low-cost, and carbon-sequestering natural resource. According to Siti 2013, bamboo is used in construction, various embellishments, paper sheet production, erosion control, and positive features towards life such as prosperity, peace, and mercy. However, she also notes the non-biodegradable of other materials compared to bamboo, environmental loss due to timber felling, and climate change via forest clearing.

Other studies have discovered that bamboo has good mechanical (Sharma et al., 2021; Su et al., 2021) and ornamental properties (Zheng et al., 2021). It has a proven ability to replace concrete and wood structures in terms of mechanical properties (Li et al., 2021). Bamboo construction materials are potential organic building materials for sustainable development (Nurdiah and Sciences, 2016).

2.1 Bamboo as Sustainable Construction Material

A study found in the construction industry states that bamboo envelope performs better than conventional brick and reinforced cement buildings. Due to the cost-efficient and green construction, it can be one of the primary replacements of steel for concrete reinforcement. Nayak et al. conducted a study comparing the cost of reinforcement with bamboo reinforcement to improve the economic and ecological benefits. Bamboo has various applications in the building as it contributes towards the design of almost all the parts from the roof to the foundation, like building, support structures, piers, walls, floor, roof, and room dividers, among other things. The structures treated with chemicals or preservations span 40 years and have been proven vigorous enough to withstand earthquakes. Bagchi et al. studied various research done on bamboo as a material to replace the standard building's concrete material.

Bamboo is used in traditional houses because bamboo grows abundantly in the tropical rain forest. However, after the industrial era began, bamboo as a building material became obsolete. There is even the perception of people bamboo is considered a cheap and non-permanent material. It is also considered a low-class material, even called "the poor man timber" by many modern builders (Lobokivov, 2009).

International Bamboo and Rattan Organization (INBAR) outlines 6 out of 17 criteria under Sustainable Development Goals (SDG) that identify bamboo as a sustainable material. In addition, it stated that the critical aspect of bamboo, which is outlined below, will provide designers and architects with an opportunity under SDG 11 (Make cities and human settlements inclusive, safe, resilient, and sustainable):

"Bamboo's unique properties of being sustainable and with high tensile strength, point to a revolution that is waiting to happen. In the world of high design, more top architects and designers are specifying bamboo for their creations in urban development" (INBAR, n.d.)

After global warming and sustainability issues emerged, bamboo as a building material has been widely discussed and reviewed. As a result, some architects and builders tend to choose bamboo as a building material. This is because bamboo can be harvested quickly, which is between 3-5 years. Furthermore, planting bamboo trees will release oxygen into the air, proving its ability that industrial materials like steel, plastic, and concrete cannot perform. Therefore, bamboo has been widely known as a sustainable building material..

3.0 Methodology

The study focuses on designing the future of bamboo construction as a sustainable material in Southeast Asia, mainly in Bali. Survey on site explores visual observation and Interviews experts as a critical methodology to see the actual building construction at the site besides review on other research related. The procedures were justified after doing some literature review and seeing a bamboo expert in Bali to confirm the site to visit. The focus bamboo building was constructed between 2010 to 2022 for visual observation. The limitation at the site is a 'time constrain' within two weeks at Bali. Quite challenging to get permission to obtain complete information because the buildings are occupied (after the pandemic covid time and Bali's opened the door to the world and is fully booked), and sensitive privacy involves most hospitality organizations to do some observations.

4.0 Findings

In interviews with experts, it can be summarized that most traditional houses in Indonesia and Asia use bamboo as structural and non-structural materials. However, with the trend of approach and innovation in terms of technology, developing the quality of construction, as informed by experts, has a significant impact. Lately, there has been renewed interest in bamboo as a construction material as a highlight by Maslucha on two main areas of study involving the study of structural exploration and aesthetic characteristics of bamboo

material (L Maslucha et al., 2019). He further elaborates on a desk study of current architectural studies on bamboo architecture shown in the below diagram (Figure 1).

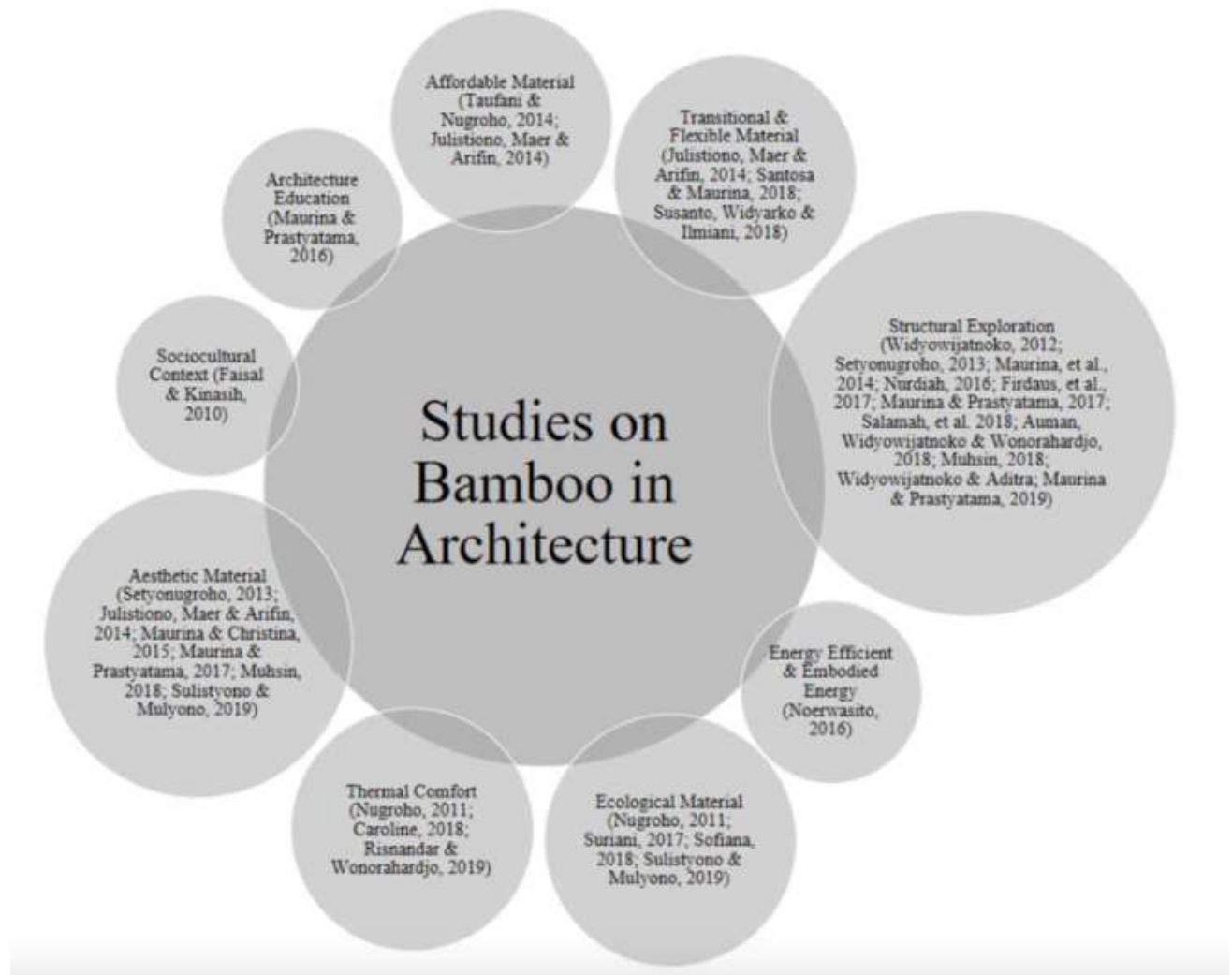


Figure 1. Range of topics in the architecture studies on bamboo material (Source:) L Maslucha (2019) & Razali M. M.A.Z (2022)

Meanwhile the study on exploring bamboo in figure 1; Maurina and A. Widyowijatnoko have published five papers on bamboo as a building material recently and contributed to exploring bamboo structural design. Moreover, L Maslucha (2019) noted other researchers exploring the aesthetic characteristics of bamboo as a building material that contributes to bamboo architectural design. Its characteristics, as strong as steel but with a degree of flexibility, also contribute to building many aseismic buildings in the earthquake-stricken area of Wenchuan, Sichuan in China, mainly built with bamboo and wood. (Shen et al., 2019).

Raw bamboo has remarkable mechanical properties and is a high-yield renewable resource (Atanda 2015). At the same time, bamboo poles as a construction material have been extensively used in vernacular buildings in its growing regions and attracted much interest from contemporary architects worldwide, such as Vo Trong Nghia, Kengo Kuma, Simon Velez and Markus Heinsdorff (Figure 2).



Figure 2: Bamboo in architecture. (a) Bb Home, Vietnam, 2013 (Image Source: H&P architects); (b) Bamboo Pavilion, Taiwan, 2019 (Image Source: ZUO Studio/Shih Hong,Yang); (c) Bamboo pavilion for Expo Shanghai, China, 2010 (Image Source: Markus Heinsdorff)

It can be seen from the field study that two-thirds of the total built from 2010 to the latest, there is a trend in Bali that uses organic design in their construction. Making this trend very noticeable and significant. With a bamboo character, as mentioned before, the designer began or revived the idea of organic architecture introduced by Frank Lloyd Wright in the early twenty century, and followers of this idea began incorporating organic shapes into the building (Star, 2019). Furthermore, this is supported by, Nurdiah (2019), mentioning and analysing several bamboo buildings in Indonesia, precisely in Bali, which is well-known as a proponent of bamboo architecture with organic shapes building.

Following the above description, selecting bamboo as a sustainable material is a fast trend today. However, bamboo is used in design; the bamboo character lends a 'rustic, which enhances the design theme, said Hardy (Hardy & TED Talk, 2015). In the interview, Hardy mentions again a material that offers a new approach that confirms the artistry needs of designers and has that uniqueness of design will create demand for a search for new material.

Bamboo, which has more characteristics, such as the capability to bend, as shown (Figure 3) by Ibuku (Ibuku & Hardy, 2021), provides a new way for designers to express their design intention. This latest interest in bamboo, especially its capability to bend in organic styles. At the site, the material highlights the best species, such as *Dendrocalamus asper* (Buluh Betong), used comprehensively for the latest trend in building an organic building in Southeast Asia. This bamboo species is considered among the strongest bamboo in this region. The organic architecture comprises a literal relation between a building and its environment; a building should integrate itself with its site (Cruz, 2012). At the same time, the term organic shape term may have a slightly different meaning than organic architecture term. The organic form can be described as a form that has been generated or created inspired by natural forms in nature, and organically inspired structural systems typically exhibit attractive aesthetic qualities that are not necessarily intuitive (Sarkisian et al., 2008). Furthermore, the adaptation of natural forms usually generates some irregular geometries.



Figure 3. (a) Sharma Spring, Bali – 6 level with 750 sqm home (Image Source: Ibuku, Zaff Taib) 2022, (b) The Study of Structure for Wind and Strength - The Indonesia Culture, Tourism, Commerce Exhibition Centre of National Bamboo Structure Expo, China 2019 (Image Source: Studio WNA)

5.0 Discussion

The conclusion that can be made is that it has become a very significant trend, and it gives a trademark and brand to Bali, and this is what they need because most of the buildings in Bali built from bamboo are related to hospitality, as resorts, hotels, restaurants, and clubs. The construction requires builders who are experts and skilled in bamboo construction and design by the designers. Due to its unique construction with sustainable bamboo material and close nature character, it is highly souled by the residents. Because bamboo can be flexed, it becomes unique. By some designers and scholars, irregular geometries are called 'freeform' and are not entirely irregular or shaped without any pattern. However, a shape of various forms becomes a spline curve (Veltkam, 2007). Moreover, Veltkam has explained that freeform can be developed by transforming primitive geometries. Primitive geometries are elements of zero to three dimensions: points, curves, surfaces, and volumes. The applied transformation consists of extrusion, scaling, and rotating. Geometric shapes then affect constructive geometry, which describes how the geometry was constructed.



Figure 4. (a) Green School Sport Hall, Bali (Image Source: Ibuku, Zaff Taib) 2022, (b) luxury Ulaman Resort Bali 2020 (Image Source: Inspiral Architecture and Design Studios, Wandersky, Kevin Mirc, Bianca Blajovan, Nora Brown, Symbiosis Studio) and The Indonesia Culture, Tourism, Commerce Exhibition Centre of National Bamboo Structure Expo, China 2019 (Image Source: Studio WNA)

Meanwhile, Materials in architecture is should be use based on its nature. As Sandaker (2008) has mentioned:

"Form 'resides' in the material, and is made explicit by respecting the qualities and properties, or the 'nature', of that material. Form is conceived irrespective of the material, and is as such free to evolve without preconditions for realisation in a specific material."

The use of materials in architecture should consider the character and properties of the materials because materials play a role in generating a form.

As a result, the evolution of building shape and form has become more dynamic, moving, and flowing. Bamboo is pushed to the limit to find what bamboo can do in a building, what shape and form can be developed using bamboo, and what suitable system is needed to design a unique bamboo building. For example, Green School is a school building built using bamboo as the primary structural material. Initiated by John Hardy, the school complex building finally won the Aga Kahn award in 2010. The latest building is the Green School Sports Hall by Ibuku, the new Ulaman Eco-luxury Resort by Inspiral Architecture and Design Studios in Bali, and The Indonesia Culture, Tourism, Commerce Exhibition Centre of National Bamboo Structure Expo by Studio WNA in China (Figure 4).

6.0 Conclusion

The use of bamboo as a sustainable building material in organically shaped buildings proved vast potential because bamboo's nature and properties can accommodate it for future construction. Organically shaped building, as a trend, generally develops using a form active structure system or semi form active system. However, it is also possible to use a non-form active structure system. Several methods can be done to curve or bend the bamboo into the desired shape, whether using the hot or cold bending methods. Besides hot bending and cold bending, curvature shapes also can be generated by connected natural curve bamboo. Nearby the understanding of the nature and properties of bamboo, the knowledge about structure system and bending method, the knowledge about joinery system is also needed.

However, using bamboo as sustainable building material still raises a question about the preservation method. Therefore, observing and performing continuous research on effective and environment-friendly preservation methods using a traditional method, minimal or without chemical ingredients, to minimize adverse environmental impacts is critical. Therefore, we can use bamboo reliably and responsibly for future construction. Changing such notions and perceptions through architectural constructions provides a more dramatic and exciting solution. With that, it can make it one of the materials that can go further into the future.

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Paper Contribution to Related Field of Study

Sustainable Environment

References

- Ahmad, Y. (2001). Study on specimen shapes for tensile test of Malaysia bamboo. In *IOP Conference Series: Earth and Environmental Science* (Vol. 220, Issue 1). University of California Press. <https://doi.org/10.1088/1755-1315/220/1/012027>
- Atanda, J. (2015). Environmental impacts of bamboo as a substitute constructional material in Nigeria (Book Section). Case stud. Constr. Mater. Vol. 03 2015
- Azmy, H. M., & Appanah, S. (1991). Bamboo resources conservation and utilization in Malaysia. *FRIM, Kepong, Kuala Lumpur, Malaysia.*, 1–13.
- Cruz, C. A. (2012). Wright's Organic Architecture: From Form Follows Function to Form and Function are One. *Wolkenkuckucksheim Issue 32*. Vol. 17. 2012.
- Ibuku, & Hardy, E. (2005). TED Talk, *Magical Houses, made of bamboo*
- Ibuku, & Hardy, E. (2021). TED Talk, *Kura Badminton Court*.
- Ige, O.E., Olanrewaju, O.A., Duffy, K.J., Collins O.C., (2021). A review of effectiveness of life cycle assessment for gauging environment impacts from cement production. *J. Clean. Prod.* 129213
- INBAR. (n.d.). *Bamboo, Rattan and the SDGs*. Retrieved (November 12, 2021), from <https://www.inbar.int/wp-content/uploads/2017/02/INBAR-Position-Paper-Bamboo-Rattan-the-SDGs>.
- Johnson, D.L., S.H. Ambrose, T.J. Bassett, M.L. Bowen, D.E. Crummey, J.S. Isaacson, D.N. Johnson, P. Lamb, M. Saul, and A.E. Winter-Nelson. (1997). Meanings of environmental terms. *Journal of Environmental Quality* 26: 581–589.
- L Maslucha, Y E Putrie, S Rahma, A N Handryant, & v Ramardani. (2019). Contribution of bamboo materials in architecture education towards sustainable community development. *IOP Conference Series: Earth and Environmental Science*, 456. <https://iopscience.iop.org/article/10.1088/1755-1315/456/1/012047/pdf>
- Li, H., Li, H., Hong, C., Xiong, Z., Lorenzo, R., Corbi, I., et al., (2021). Experimental investigation on axial compression behavior of laminated bamboo lumber short columns confined with CFRP. *Compos. A: Appl. Sci. Manuf.* 150, 106605

- Lobokivov, M., Lou, Y., Schoene, D., Widenoja, R. (2009). The Poor Man's Carbon Sink: *Bamboo in Climate Change and Poverty Alleviation*. Rome: FAO.
- Nurdiah, E.A Sciences, B., 2016. The potential of bamboo as building material in organic shaped buildings. *Procedia-Social*. 216, 30-38
- Razali M. M.A.Z. (2022), The bamboo bending capabilities as landscape structures for sustainable build environment construction: Case study of *Dendrocalamus Asper*, *Master Thesis UiTM*
- Sandaker, B. N. (2008). *On Span and Space: Exploring Structure in Architecture*. New York: Routledge.
- Sarkisian, M., Lee, P., Long, E., Shook, D. (2008). *Organic and Natural Forms in Building Design*. CTBUH Technical Paper.
- Sharma, B., Eley, D., Emanuel, O. Brentnall, C., (2021). Mechanical properties of laminated bamboo designed for curvature. *Constr. Build. Mater* 300, 123937
- Shen, L., Yang, J., Zhang, R., Shao, C., & Song, X. (2019). The Benefits and Barriers for Promoting Bamboo as a Green Building Material in China—An Integrative Analysis. *Sustainability*, 11(9), 2493. <https://doi.org/10.3390/su11092493>
- Star, S. (2019). *Organic Architecture* dtc. July. <https://doi.org/10.13140/RG.2.2.21305.11364>
- UNISDR *The International Strategy for Disaster Reduction*, 2004-03-31. Retrieved 2010-06-09.
- Veltkam, M. (2007). *Free Form Structural Design: Schemes, Systems, Prototypes of Structures for Irregular Buildings*. Delft: Delft University Press.
- Warner, K.; Hamza, H.; Oliver-Smith, A.; Renaud, F.; Julca, A. (December 2010). "Climate change, environmental degradation and migration". *Natural Hazards*. 55 (3): 689–715
- Zheng, J., Tarin, M.W.K., Jiang, D., Li, M., Ye, J., Chen, L., et al., (2021). Which ornamental features of bamboo plants will attract the people most? *Urban forestry Urban Greening*. 61, 127101