AMERICAN JOURNAL OF MULTIDISCIPLINARY RESEARCH AND INNOVATION (AJMRI)

ISSN: 2158-8155 (ONLINE), 2832-4854 (PRINT)

VOLUME 2 ISSUE 2 (2023)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Multidisciplinary Research and Innovation (AJMRI)

Volume 2 Issue 2, Year 2023
ISSN: 2158-8155 (Online), 2832-4854 (Print)
DOI: https://doi.org/10.54536/ajmri.v2i2.1406
https://journals.e-palli.com/home/index.php/ajmri

Flexural Strength of Reinforced - Bamboo Concrete Infill Structural Beam Subjected to Concentrated Load at Midspan

Cesario A. Bacosa Jr.[1*], Michael E. Loretero[2]

Article Information

Received: March 19, 2023

Accepted: April 03, 2023

Published: April 06, 2023

Keywords

Flexural Strength, Reinforced - Bamboo Culm Beam, Concrete Infill, Bamboo Culm. Bamboo Concrete Infill

ABSTRACT

Bamboo is still considered a material for poor people in rural areas. Still, it also has the potential to be fully developed engineering material reinforced structural beams with concrete infill to increase the structural strength of the structures, which is natural aesthetic, and more durable than bamboo alone as structural parts of buildings. This study aims to determine the flexural strength of bamboo with concrete infill as a structural beam subjected to a concentrated load at midspan. The materials used were whole bamboo culms, specifically *Dendrocalamus Asper Schultes, Dendrocalamus Merrillianos Elmer, Bambusa Vulgaris Schrad, and Bambusa Blumeana Schultes* cut into 600 mm lengths and treated with seawater and seawater with mango polyphenol infilled with concrete. The concrete was cured for 7, 14, 28, and 56 days, respectively. The results showed that the whole bamboo culm treated with seawater and treated with seawater plus a 10 percent solution of mango polyphenol extract remarkably increased its flexural strength. The concrete infill to the whole bamboo culm as the beam is effective, increasing flexural strength when treated with mango polyphenol. The curing age of concrete and treatment of bamboo culm with seawater and mango polyphenol affects the flexural strength of reinforced bamboo with concrete infill subjected to a concentrated load at midspan. Reinforced bamboo concrete infill-based construction materials can reduce pressure on resources and the environment. These materials have environmental and mechanical advantages over conventional construction materials.

INTRODUCTION

Bamboo is a renewable and versatile resource characterized by high strength and low weight and can be easily operated using simple tools. From early times, Bamboo has been used as a construction material. The main obstacle to the application of bamboo as a reinforcement is the lack of sufficient information about its interaction with concrete, strength, and durability, as supported by Van der Lugt *et al.* (2006); Bamboo as a building material determinant factor of success and failure of buildings with bamboo that can be competitive with materials more commonly used. As reiterated by Mosallama (2017), Bamboo has a very long history with humankind, is one of the oldest building materials used for construction Sudhakar *et al.* (2008) has various structural components have been developed using bamboo concrete composites (*Bamcrete*) and demonstrated in building houses. Bamboo is used for construction purposes. Bamboo possesses excellent mechanical properties compared with other commonly used construction materials.

As Wei *et al.* (2011) mentioned, bamboo structures' application outlook and advantages are discussed according to the design and construction practices of modern bamboo structure demonstration buildings. According to Awoyera and Adesina (2017), the structural integrity of sensitive materials used for construction, and the structural integrity assessment of bamboo for construction purposes, is considered that different materials perform differently under specific loading and environmental conditions. As stated by Moran *et al.* (2017), Bamboo is a sustainable material with a high potential for structural applications, including failure strain and stress. As mentioned by Gatoo *et al.* (2014). Structural and engineered bamboo products are comparatively low energy-intensive materials with sufficient structural properties for modern construction. The design and construction of bamboo buildings are suitable for construction applications, the development of bamboo-based products, and the types of structures typically designed and built with bamboo Correal (2016). Design considerations include bamboo testing, structural design standards, and building codes.

According to (Wang *et al.*, 2012), the strength of bamboo as a concrete reinforcement is much lower than that of steel reinforcement; Due to excellent properties like high strength-to-weight ratio, high tensile strength, and free-cutting and processing, bamboo as a potential reinforcement material in place of steel is widely available in concrete structural elements, such as bamboo reinforced concrete columns, beams, slabs, and footing.

Bamboo has been widely used as a renewable structural material for building permanent and temporary structures in recent decades. However, the compressive bearing capacity of bamboo is relatively low, which limits its applications only to forms under light loads and the load-bearing capacity of bamboo by filling concrete or cement mortar in bamboo cavities supported by Geymayer and Cox (1970).

According to Kankam (1988), bamboo-reinforced concrete supported beams were tested for failure under

[1] Western Philippines University, San Juan, Aborlan, Palawan, Philippines
[2] School of Engineering, University of San Carlos, Cebu City, Philippines
[*] Corresponding author's e-mail: bacosa081976@yahoo.com

third-point loading, and six other beams were subjected to long-term loading. The collapse of the ten beams occurred mainly through the diagonal tension failure of the concrete in the shear span and shear strength of the concrete. In addition, Yu *et al.* (2003) reiterated that column buckling is considered one of the critical modes of failure in bamboo, often leading to its overall collapse, confirmed by Yu *et al.* (2005).

The axial buckling behavior of bamboo columns failed in the axial buckling behavior of bamboo columns owing to the culm holes. As stated, Sudhakar *et al.* (2008) have developed various structural components using bamboo concrete composites (*Bamcrete*), demonstrated them in building houses, and experimentally verified structural arch forms using bamboo as a structural element. As mentioned by Bhagat *et al.* (008). According to Terai and Minami (2012), the mechanical behavior of bamboo-reinforced concrete members, the difference in the structural properties of steel-reinforced concrete and bamboo-reinforced concrete, and the mechanical properties of bamboo-reinforced concrete members are studied. As cited by Gupta and Bhalla (2013). modern bamboo structures have excellent structural properties, confirming that the capacity of these bamboo composites is comparable in strength with similar reinforced concrete (RC) and modern engineered bamboo structures, which makes it possible to replace RC wherever required and thought acceptable.

Bamboo materials are often characterized using standard tension coupon tests. However, because of the functionally graded nature of bamboo, the standard tension test geometry needs to be revised. It may result in additional non-uniform bending stresses being introduced across the breadth of the cross-section during testing Richard & Harries (2016). According to Li *et al* (2017). An experimental study on the axial load behavior of material-filled structural bamboo was conducted to investigate the effects of infilled materials, horizontal stiffeners, and bamboo nodes. Moran *et al.* (2017) state that effective circumferential moduli under compression are like those obtained under tension. Consistent behavior was observed between the pressure and compression tests. All functions could simulate the elastic distribution through the wall thickness of bamboo, as shown in other studies. These flexible distributions are species-dependent.

According to Zhong *et al.* (2017), reinforcement and bamboo elements could form an integrated composite cross-section. The failure modes, ultimate load, and cross-sectional stiffness of the RBSC beams were significantly correlated with the reinforcement's diameter and the bamboo bundle's heat treatment. This preliminary study will be beneficial for designing, manufacturing, and applying bamboo-based structural composite materials in practical engineering. As mentioned, Zhong *et al.* (2017) compared the RSBC beam with other un-reinforced beams to evaluate its bending properties. The results indicated that the reinforcement and bamboo elements could form an integrated composite cross-section. Typical failure modes include cracks along the longitudinal direction of the bamboo element, a break along the vertical movement of the bamboo element, and shear failure.

This research aims to determine the structural strength of untreated, treated with seawater, and seawater with mango Polyphenol Bamboo culm with concrete infill. Structural beams to determine the flexural strength of the bamboo culms, bamboo culm as beams were reinforced with concrete infill and bamboo culm beams without concrete infill to determine the significant difference between the flexural strengths of bamboo culms as a beam of different species when Untreated, treated with sea seawater, treated with seawater plus 10 percent solution of mango polyphenol, No concrete infill, and Infill with concrete.

METHODOLOGY

The specific methods and procedures are enumerated as follows.

Step 1. The three-year-old matured bamboo was selected carefully, and harvested bamboo Species were used as a material. In this study, Philippines Bamboo species were utilized preferably where the abundance of these four species can be found, specifically the *(a) Dendrocalamus Asper Schultes, (b)Bambusa Blumeana Schultes, (c) Bambusa Vulgaris Schrad and (d) Dendrocalamus Merrillianos Elmer.*

(a) (b) (c) (d)

Figure 1: (a) *Dendrocalamus Asper Schultes*, (b)Bambusa Blumeana Schultes, (c) Bambusa Vulgaris Schrad and (d) *Dendrocalamus Merrillianos Elmer.*

Step 2. The selected Philippine bamboo species were cut with 600 mm length with one or two nodes. Each bamboo species had three samples for each treatment and was stocked, as shown below.

(e) harvested Matured bamboo. **(f) Cut with one -node.** **(g) Cut with two-nodes**

Figure 2: (e) Harvested Matured Bamboo (f) Cut with one -node (g) Cut with two-nodes

Step 3. After cutting the bamboo according to a specified length. The Bamboo treatments were undertaken as follows: (h) Untreated (Kiln Drying), naturally soaked, (i) Treated with seawater, and (j)Treated with seawater plus Mango Polyphenol. The treatment was Naturally soaked for seven days, 14 days, 28 days, and 56 days.

(h) **(i)** **(j)**

Figure 3: (h) Untreated (Kiln Drying), naturally soaked, (i) Treated with seawater, and (j)Treated with seawater plus Mango Polyphenol.

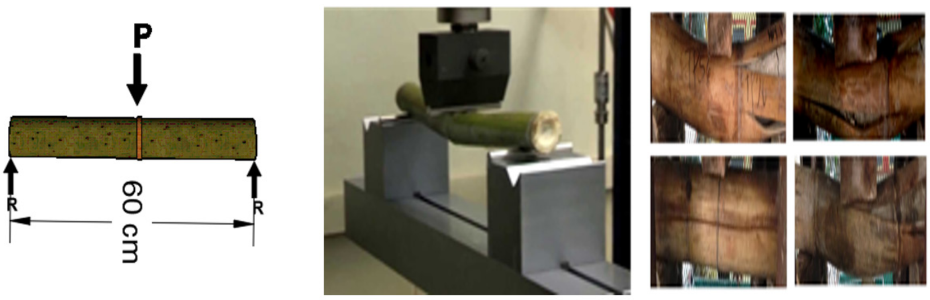
Step 4. Preparations of concrete infill materials (Cement, sand, and gravel), Type 1 cement is used, and sand and gravel properties were controlled based on ASTM Standards. The bamboo nodal tubes were carefully removed, and the Concrete Infill materials were carefully filled in the bamboo Culms. The bamboo culm concrete infill was stocked (k), (l), (m) at average room temperature for curing.

(k) **(l)** **(m)**

Figure 4: The bamboo culm concrete infill was stocked (k), (l), (m) at average room temperature for curing.

Step 5. Curing of concrete infill. Infill the Bamboo culms with concrete cured for 7, 14, 28, 56and days according to ASTM standards. The bamboo concrete infill was curing at room temperature figures (k to m).

Step 6. Testing of the Samples: After curing the Concrete in fill inside the bamboo Culm each sample was tested for its flexural strength using Universal Testing Machine subjected to concentrated loading at midspan. The results were tabulated and analyzed carefully. Laboratory tests were performed according to ASTM standards.



(n) Flexural test Set-up **(o) Actual flexural Testing** **(p) Actual Flexural Failures**

Figure 5: Testing of the Samples

RESULTS AND DISCUSSION

The selected bamboo species were selected subjected to no treatment, treated with seawater, and treated with seawater plus a 10 percent solution of mango polyphenol extract for seven days, 14 days, 28 days, and 56 days respectively, (Pradhan, N. P., *et al.*, 2022) filled with concrete infill having a water cement ratio of 0.50 and cured for seven days, 14 days, 28 days and 56 days tested using universal testing machine subjected to a concentrated load at mid-span the results were presented below.

Table 1: Flexural Strength of Whole bamboo column without Concrete infill

Curing Age (Days)	Bamboo Culm without Infill - Flexural Strength (MPa)											
	Dendrocalamus Merrillianos Elmer			**Bambusa Vulgaris Schrader**			**Bambusa Blumeana Schultes**			*Dendrocalamus Asper Schultes*		
	DME-Untreated (Kiln Drying)	DME - Seawater Treatment	DME-Seawater + Mango Polyphenol Treatment	BVS-Untreated	BVS- Seawater treatment	BVS- Seawater +Mango Polyphenol Treatment	BBS-Untreated	BBS-Seawater Treatment	BBS-Seawater +Mango Polyphenol Treatment	DAS-Untreated	DAS-Seawater Treatment	DAS-Seawater +Mango Polyphenol Treatment
7	8.61	8.96	9.99	8.27	8.61	9.65	6.89	8.61	9.65	8.96	9.65	10.34
14	8.96	9.65	10.75	8.61	9.30	10.34	8.27	9.23	10.34	8.96	10.34	11.02
28	9.65	10.34	11.51	8.96	9.99	11.02	8.96	9.85	10.82	9.65	11.02	11.71
56	9.65	11.02	12.06	9.65	10.68	11.71	9.65	10.47	11.58	10.34	11.37	12.40

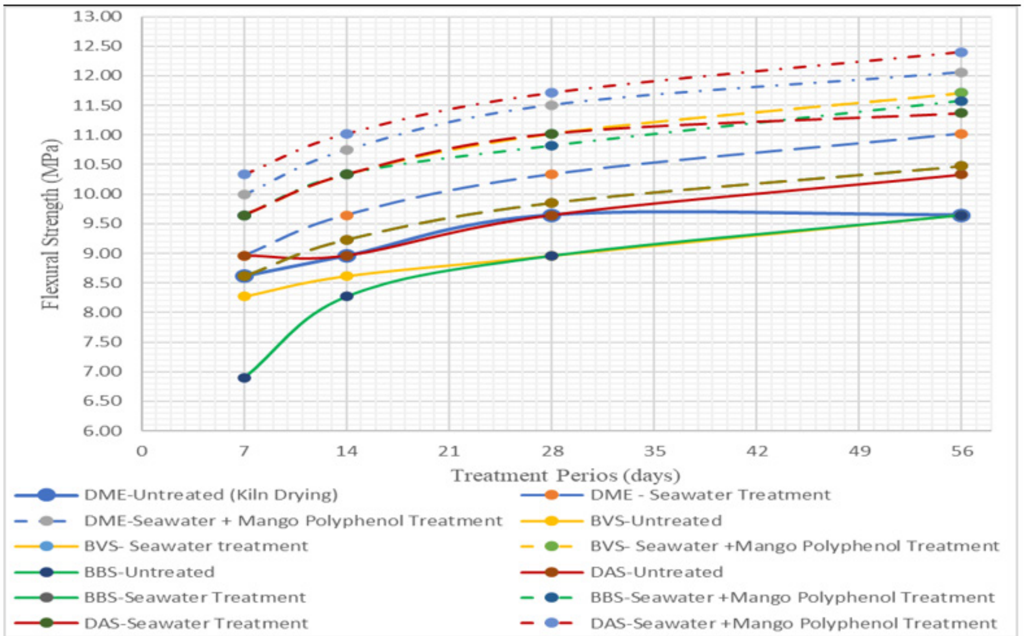


Figure 6: Flexural Strength of Whole bamboo column without Concrete infill.

The table and graph reveal that Bamboo culm without concrete infill among the specie *Dendrocalamus asper Schultes* had the highest flexural strength of 10.34 MPa for untreated and 11.37 MPa for treated with seawater for 56 days and 12.40 MPA for treated with seawater plus 10 percent Mango Polyphenol for 56 days. An increase in Flexural strength of an average of 10 percent every treatment period is remarkable, and a rise of 10 percent for each treatment is also significant. *Dendrocalamus Merrillianos Elmer* also shows high flexural strength of 12.06 MPa when treated with seawater plus 10 percent mango polyphenol. Bambusa Blumeana Schultes shows remarkably increased flexural strength after treatment with seawater, a 10 percent solution of mango polyphenol extract, and *Bambusa Bulgaris Schrader*. This implies that among the species, *Dendrocalamus Asper Schultes* has the highest flexural strength, followed by *Dendrocalamus Merrillianos Elmer* when treated because of its cell wall, strengthen the study of Amatosa, T. A. *et al.* (2021) treatment with seawater and 10 percent solution of mango polyphenol affects the bending stress of bamboo culm subjected to a concentrated load at midspan. The table

Table 2: Flexural strength of bamboo culm beam reinforced with concrete infill.

Curing Age (Days)	Bamboo Culm without Infill - Flexural Strength (MPa)											
	Dendrocalamus Merrillianos Elmer			*Bambusa Vulgaris Schrader*			*Bambusa Blumeana Schultes*			*Dendrocalamus Asper Schultes (DAS)*		
	DME-Untreated (Kiln Drying)	DME - Seawater Treatment	DME-Seawater + Mango Polyphenol Treatment	BVS-Untreated	BVS- Seawater treatment	BVS- Seawater +Mango Polyphenol Treatment	BBS-Untreated	BBS-Seawater Treatment	BBS-Seawater +Mango Polyphenol Treatment	DAS-Untreated	DAS-Seawater Treatment	DAS-Seawater +Mango Polyphenol Treatment
7	11.02	11.02	12.06	10.34	10.68	11.71	8.96	10.68	11.71	11.02	11.71	12.40
14	13.54	12.92	14.02	11.89	12.57	13.78	11.71	12.68	13.78	12.23	14.64	16.19
28	14.23	13.61	14.78	12.23	13.26	14.47	12.40	13.30	15.98	12.92	15.33	16.88
56	13.99	14.30	16.40	13.09	13.95	14.81	12.92	13.75	16.50	13.44	14.47	17.67

shows the increase in flexural strength when subjected to a concentrated load at mid-span. Among the species, infill with concrete *Dendrocalamus Asper Schultes* having a flexural strength of 17.67 MPa treated with seawater plus mango polyphenol shows remarkable improvements due to the larger hollow culms filled with concrete cured in 56 days, and the *Bambusa Blumeana Schultes* that were treated with 10 percent solution mango polyphenol for 56 days with a flexural strength of 16.50 MPa and *Dendrocalamus Merrillianos Elmer* having a flexural strength of 16.40 MPa treated with seawater plus mango Polyphenol for 56 days curing. Among the species, *Dendrocalamus Asper Schultes* has the highest flexural strength when infusing concrete. This implies that bamboo culm concrete infill Nie, Y. *et al.* (2022) significantly contribute to the increased flexural increase as well the bamboo treatment process and period of concrete curing. With these results, Chen, Z.*et al.* (2022) bamboo–concrete reinforcement infill is suitable for more robust and durable building materials.

Reiterated that application technology of bamboo-reinforced concrete elements in building structures when bamboo culm strengthened with concrete infill to concrete columns and beams Lokendra, K., & Maurya, M. C. (2017).

Table 3: ANOVA: Comparison between the flexural strength of bamboo culm without concrete infill when untreated (kiln dried), treated with seawater, and treated with seawater plus a 10 percent solution of mango polyphenol.

Source of Variation	SS	DF	MS	F	P-Value	F Crit
Bamboo culm treatment.	513272.9	3	171091	37.464	0.000	*2.891
Bamboo species.	147356.3	11	13396.02	2.933	0.008	*2.093
Error	150702.1	33	4566.73			
Total	**811331.3**	**47**				

* *(Means are Different)*

Table 3 shows a significant difference between the bamboo species and their flexural strength because the f value of 37.464 exceeds the f-critical value of 2.891 tested at a confidence level of 0.05. There is also a significant difference between the flexural strength of untreated bamboo, bamboo treated with seawater, and bamboo treated with a 10 percent solution of mango polyphenol. The flexural strength significantly differs when bamboo species are compared because the f value of 2.933 is greater than the f critical value of 2.092, tested at a significance level. This implies that the bamboo's flexural strength depends on its spices and treatment of bamboo culm and treatment period; however, the concrete infill Huang, T., & Zhuo, X. (2022) significantly increased its flexural strength of the bamboo Culm subjected to Midspan loadings Weifeng, Z. *et al.* (2012),

Table 4: ANOVA: Comparison between the flexural strength of bamboo culm as a beam infill with concrete when untreated (kiln dried), treated with seawater, and treated with seawater plus a 10 percent solution of mango polyphenol.

Source of Variation	SS	DF	MS	F	P-Value	F Crit
Bamboo Species	6473958	3	2157986	47.363	0.000	*2.891
Bamboo Culms concrete infill	1222292	11	111117.4	2.438	0.024	*2.093
Error	1503542	33	45561.87			
Total	**9199792**	**47**				

**Means are Different*

Table 4 shows a significant difference between the bamboo species and their flexural strength because the f value of 47.363 exceeds the f-critical value of 2.891 tested at a confidence level of 0.05. There is also a significant difference between the flexural strength of bamboo culm with infill and no infill when the bamboo culms are untreated, treated with seawater, and treated with seawater plus 10 percent solution of mango polyphenol because the f value of 2.438 is greater than the f critical value of 2.093, tested at 0.05 level of significance. This implies that the bamboo's flexural strength depends on its spices and treatment periods, curing of concrete infills; however, Fahim M. *et al.*(2022)bamboo culm with the concrete infill significantly) increased its flexural strength. Thus, Archilla H. *et al.* (2018) Concrete infills strengthen the bamboo culms and increase their flexural strength, which is more durable. The strength of bamboo culm reinforcement infill concrete reinforcement is much lower than steel bar reinforcement, but its flexural strength increased. However, one of the merits is that a cheap, replenishable, abundantly available material makes Bamboo a potential structural beam when adequately treated and reinforced with concrete infill, according to Zhao W. F. *et al.* (2012). Bamboo-supported concrete elements in building structures and Sudhakar *et al.* (2008), such as bamboo-reinforced concrete columns, beams, slabs, and walls.

CONCLUSION

Bamboo culm is a versatile material reinforced with concrete infill suitable for construction, sustained by the claims of Fahim M. *et al.* (2022). The whole bamboo culm treated with seawater and mango polyphenol showed remarkably increased flexural strength, thus soaking bamboo culm in seawater plus mango Polyphenol is a good treatment agent, and the process strengthens the claim of Amatosa, T. A. *et al.* (2021). Among the species, *Dendrocalamus Asper Schultes* and *Dendrocalamus Merrillianos Elmer* had the highest flexural strength without concrete infill when treated with seawater plus mango Polyphenol for the specified period.

The concrete infill to the whole bamboo culm as the beam is effective, increasing the flexural strength supports Li Y. *et al.* (2015) claim. Among the bamboo species, *Dendrocalamus Asper Schultes* and *Dendrocalamus Merrillianos Elmer* had the highest flexural strength treated with Mango Polyphenol extract after 56 day curing period, wherein bamboo- concrete infill is a potential alternative material for low-cost housing, reiterated by Mallikarjun, B. R. *et al.* (2021);.

The curing age of concrete and treatment of bamboo Goh, Y. *et al.* (2020). Culm with seawater and mango polyphenol affects the flexural strength of bamboo culm beam infill with concrete subjected for loading at midspan. Reinforced bamboo culm infill with concrete is an alternative construction material that is more durable and stronger than bamboo culm as a beam with no infill, Zhao, W. F. *et al.* (2012). The concrete infill can significantly strengthen the reinforced bamboo culm, reducing the strength-to-weight ratio (Ramesh M. *et al.*, 2021). This resulted in the potential for structural applications of bamboo culm-enhanced composites.

RECOMMENDATION

Bamboo concrete infill is suitable as a low-cost material for flexural and bending; however, proper treatment and curing of concrete infill must be addressed, and adequate bamboo culm drying must be performed. Among the bamboo species, *Dendrocalamus Merrillianos Elmer* and *Dendrocalamus Asper Schultes* with concrete infill are recommended for beams and joists provided bamboo culm will be appropriately treated at a specified rate period and proper curing of concrete infill for more extended periods. Hence, bamboo culm concrete infill can be recommended as an excellent potential low-cost housing construction material.

Acknowledgment

The authors want to acknowledge the Philippine Department of Science and Technology – Engineering Research Developments and Technology for research grants and funding.

REFERENCES

Awoyera, P. O., & Adesina, A. (2017). Structural integrity assessment of bamboo for construction purposes.

Archila, H., Kaminski, S., Trujillo, D., Zea Escamilla, E., & Harries, K. A. (2018). Bamboo reinforced concrete: a critical review. *Materials and Structures, 51,* 1-18.

Amatosa, T. A., Loretero, M. E., Taboada, E. B., & Lim, K. J. (2021). Influence of Mango Polyphenol Treatment in Mechanical Properties of Dendrocalamus Asper Bamboo. *SPECTA Journal of Technology, 5*(2), 153-159.

Bhagat, D., Gupta, M., & Bhalla, S. (2013). Design and strength analysis of composite bamboo column elements. *IOSR J. Engg (IOSRJEN), 3*(6), 31-36.

Correal, J. (2016). Bamboo design and construction 14. Nonconventional and Vernacular Construction Materials: Characterization, Properties, and Applications.

Chen, Z., Ma, R., Du, Y., & Wang, X. (2022, January). State-of-the-art review on research and application of original bamboo-based composite components in structural engineering. *In Structures, 35,* 1010-1029. Elsevier.

Fahim, M., Haris, M., Khan, W., & Zaman, S. (2022). Bamboo as a construction material: Prospects and challenges. *Advances in Science and Technology Research Journal, 16*(3), 165-175.

Gatóo, A., Sharma, B., Bock, M., Mulligan, H., & Ramage, M. H. (2014, October). Sustainable structures: bamboo standards and building codes. *In Proceedings of the Institution of Civil Engineers-Engineering Sustainability 167*(5), 189–196. Thomas Telford Ltd.

Geymayer, H. G., & Cox, F. B. (1970). Bamboo reinforced concrete.

Gupta, A., & Kumar, A. (2008). The potential of bamboo in sustainable development. *Asia Pacific Business Review, 4*(3), 100–107.

Goh, Y., Yap, S. P., & Tong, T. Y. (2020). Bamboo: the emerging renewable material for sustainable construction. Encyclopedia of Renewable and Sustainable Materials, 2, 365-376.

Huang, T., & Zhuo, X. (2022). Experimental study on the bending properties of grouting butt joints reinforced by steel plate embedded in a bamboo tube. *Journal of Renewable Materials, 10*(4), 993.

Kankam, J. K., Ben-George, M., & Perry, S. H. (1988). Bamboo-reinforced concrete beams subjected to third-point loading. *Structural Journal, 85*(1), 61–67.

Li, Y., Shan, W., Shen, H., Zhang, Z. W., & Liu, J. (2015). Bending resistance of I-section bamboo–steel composite beams utilizing adhesive bonding. *Thin-walled structures, 89,* 17–24.

Mosallama, A. S., Ghavamib, K., Shrivastavaa, R., & Salamac, M. A. (2017). Structural Behavior Of An Innovative Bamboo Arch Structure 17th International Conference on Non-Conventional Materials and Technologies, Construction Materials & Technologies for Sustainability (17th NOCMAT 2017) 26th – 29th November 2017, Mérida, Yucatán, México.

Moran, R., Webb, K., Harries, K., & García, J. J. (2017). Edge bearing tests to assess the influence of radial gradation on the transverse behavior of bamboo. *Construction and Building Materials, 131,* 574-584.

Mallikarjun, B. R., & Shete, G. N. (2021). Experimental study on bamboo reinforcement in structural concrete element. *International Journal of Research in Engineering and Science (IJRES), 9*(8), 31-35.

Nie, Y., Wei, Y., Miao, K., Zhao, K., & Huang, L. (2022). Experimental investigation of full-culm bamboo tubes strengthened by filled concrete and bamboo sheets under axial compression. *Journal of Building Engineering, 45,* 103548.

Pradhan, N. P., Paraskeva, T. S., & Dimitrakopoulos, E. G. (2022). Simulation and experimental verification of an original full-scale bamboo truss. *Engineering Structures, 256,* 113965.

Richard, M. J., Gottron, J., Harries, K. A., & Ghavami, K. (2017). Experimental evaluation of longitudinal splitting of bamboo flexural components. *Proceedings of the Institution of Civil Engineers-Structures and Buildings, 170*(4), 265-274.

Ramesh, M., Deepa, C., & Ravanan, A. (2021). Bamboo fiber reinforced concrete composites. Bamboo Fiber Composites: Processing, Properties and Applications, 127–145.

Sudhakar, P., Gupta, S., Bhalla, S., Kordke, C., & Satya, S. (2008). Conceptual development of bamboo concrete composite structure in a typical Tribal Belt, India. *In Modern Bamboo Structures,* 77–86. CRC Press.

Terai, M., & Minami, K. (2012). Research and development on bamboo reinforced concrete structure. 15 WCEE.

Van der Lugt, P., Van den Dobbelsteen, A. A. J. F., & Janssen, J. J. A. (2006). An environmental, economic, and practical assessment of bamboo as a building material for supporting structures. *Construction and building materials, 20*(9), 648-656.

Wei, Y., Jiang, S. X., Lv, Q. F., Zhang, Q. S., Wang, L. B., & Lv, Z. T. (2011). Flexural performance of glued laminated bamboo beams. *In Advanced Materials Research, 168,* 1700-1703). Trans Tech Publications Ltd.

Wang, F., & Shao, Z. (2020). Study the variation law of bamboo fibers' tensile properties and organization. Structure on the radial direction of the bamboo stem. *Industrial crops and products, 152,* 112521.

Wei, Y., Ji, X., Duan, M., & Li, G. (2017). Flexural performance of bamboo scrimber beams strengthened with fiber-reinforced polymer. *Construction and Building Materials, 142,* 66-82.

Yu, W. K., Chung, K. F., & Chan, S. L. (2003). Column buckling of structural bamboo. *Engineering Structures, 25*(6), 755-768.

Yu, W. K., Chung, K. F., & Chan, S. L. (2005). Axial buckling of bamboo columns in bamboo scaffolds. *Engineering Structures, 27*(1), 61-73.

Zhong, Y., Wu, G., Ren, H., & Jiang, Z. (2017). Bending properties evaluation of newly designed reinforced bamboo scrimber composite beams. *Construction and Building Materials, 143,* 61–70.

Zhao, W. F., Zhou, J., & Bu, G. B. (2012). Application technology of bamboo reinforced concrete in the building structure. *In Applied Mechanics and Materials, 195,* 297–302. Trans Tech Publications Ltd.