A Review on Round Bamboo Structural Applications and Perspectives

Alessandra Simi, Roya Mostaed Shirehjini, Da Shi, Cristoforo Demartino, and Zhi Li

Abstract Nowadays, bamboo as a readily available, inexpensive, renewable raw material is increasingly used in construction in several countries around the world. In this context, the use of bamboo culm for structural applications is one of the key concepts increasingly grown over the past few decades. This is motivated by the fact that regardless of being a rough-and-ready (low-tech) material, round bamboo culms are found to be easy to implement and capable of yielding architectural and structurally high-performing light-weight constructions and building designs. In this study, we aim to review design approaches for round bamboo structures, to provide a recent state-of-the-art of the relevant scientific and technical literature.

Keywords Bamboo culm · Structural bamboo · Connections · Structural forms

1 Introduction

In the past few decades, bamboo-based building materials have progressively suggested new promising approaches in sustainable construction. Bamboo is inherently renewable, with a great potential to provide carbon–neutral raw materials in an inexhaustible system, thus providing significant environmental and economic advantages. Moreover, it is considered as the fastest growing plant species, with a growth rate that can reach up to 100 cm in a day.

As a building material, bamboo culm has been shown to have remarkable mechanical properties. In addition, it is characterized by a short rotation age: Hisham [1] concluded that a 3.5-year-old bamboo is a suitable material for construction.

A. Simi · R. M. Shirehjini
College of Civil Engineering, Nanjing University of Technology, Nanjing, Jiangsu, China

D. Shi · C. Demartino (✉)
Zhejiang University-University of Illinois at Urbana Champaign Institute, Zhejiang University, Haining, Zhejiang, China
e-mail: cristoforodemartino@intl.zju.edu.cn

Z. Li
College of Civil Engineering and Architecture, Zhejiang University, Hangzhou, Zhejiang, China

K. Liu et al. (eds.), *2019 International Bamboo Construction Competition*, Springer Tracts in Civil Engineering, https://doi.org/10.1007/978-3-030-91990-0_3

Bamboo culm has a cylindrical, hollow, anisotropic body, which makes it particularly challenging to deal with [2]. During less than three decades, there has been a significant growth in research and development on bamboo culm structures. In this review we aim to review bamboo culm application in construction and the relevant findings of previous works.

1.1 Constructing with Bamboo

Today, bamboo is a primary housing material for over one billion people [3]. Bamboo is largely used because it is cheap, locally available, has high disaster-tolerance ability due to being strong, lightweight, flexible, environmentally compatible. Stilt bamboo houses scattered in ASEAN countries and bamboo houses in South American countries are good examples of such phenomena [4]. Bamboo culms endure more lateral forces, this can mitigate damages during floods, typhoons, earthquakes. Buildings made of bamboo have been left intact whereby many concrete and masonry buildings were severely damaged during the devastating earthquakes that took place in Costa Rica (1991, Mw 7.6), Colombia (1999, Mw 6.4), Ecuador (2016, Mw 7.8) and Indonesia (2018, Mw 6.9); this can be encouraging for bamboo applications in earthquake-prone areas.

Nevertheless, despite such modern progress in this area and the successful results achieved, it must be said that, as of today, bamboo construction has been more related to those environmentally concerned communities. Indeed, bamboo culm as a structural or building material is still relatively unknown to many decision makers and clients. Besides, there is little standardization and few design criteria, which could challenge the designers and lead to loss of confidence and acceptance among them.

1.2 Mechanical Properties

No two bamboo culms are completely alike; indeed, both physical and mechanical characteristics of bamboo culms, can be unique for each bamboo species and even for every single culm. Thus, the mechanical properties should be related to the physical characteristics of bamboo culms.

Table 1 shows approximate values of key mechanical properties of some structural bamboo species observed and recorded by different authors.

Table 1 Literature mechanical properties of some structural bamboo species

Bamboo species	TS (MPa)	CS (MPa)	SS (MPa)	BS (MPa)	References
Guadua angustifolia	143	40–43	8	209	[5]
Phyllostachys pubescens	115–309	48–60	11–15	9–27	[6, 7]
Phyllostachys edulis	129–193	69	15	–	[8–10]
Dendrocalamus asper	232	73	7	20	[11]
Bambusa vulgaris	232	78	8.5	20	[11]

TS = Tensile Strength; CS = Compressive Strength; SS = Shear Strength; BS = Bending Strength

2 Design and Implementation

2.1 Modeling and Form-Finding

Dealing with a round bamboo culm is affected by uncertainty and ambiguity. The difficulty of constructing with bamboo often lies in the wide differences in structural and dimensional features among different bamboo culms and even within the same culm. This makes bamboo culms dependent on many variables, which require time-consuming measurements and complex computational procedures. Consequently, this may lead to a lack of confidence in designing suitable forms and geometries.

To carry out physical modelling in structural design, many studies have suggested to ease geometrical and structural analysis and to enhance computational accuracy [12]. Once the detailed structural models and their form are well-understood, they are transformed into a digital model. The approach is twofold: either physical modelling or digital simulation.

Physical modelling has been used to identify optimum assembly plans and to generate functional forms of structures [13, 14]. The physical form-finding method has been also used extensively in active-bending bamboo structures (e.g., domes, arches, tensile grid shells) [15, 16]. This approach is only based on experimental form-finding without numerical calculations.

As for the digital simulation approach, two powerful and commonly used digital tools are Grasshopper® and Rhinoceros® with Kangaroo and Karamba3D [17] plugin for computational simulation and form-finding of bamboo structures [18–20]. These programs resemble finite element analysis methods [5, 16, 21, 22].

2.2 Joints

The approach used to construct and implement bamboo structures is comparable with that of timber; joining lightweight structural components together by means of connectors. Joints (or connectors) as critically important aspect of bamboo structures are to ensure an efficient load bearing system or otherwise it can be the main cause of failure in structural stability and performance [23].

Lashing or ropework can be considered as most widely used bamboo connecting method. Despite being an old technique, lashing is being used in assembling several modern bamboo structures. The ropes used for lashing purpose can be made of natural fibers such as hemp, lime bast, coir, rattan and bamboo, or synthetic fibers such as polyester cords.

Bolts, as simple but strong and efficient mechanical fastening, offer opportunities that traditional lashing joints do not. This technique requires drilling holes on the wall of the bamboo culms and to use bolts and nuts to fasten and secure the joints between the bamboo components. Different forms of bolted bamboo connections have been proposed: using multi-bolted joint [23–25], or other supporting means such as hooks [23], mounting inner U-shaped metal plates [26], natural fiber straps [27] to secure the bolts from loosening and disengaging.

Clamped joints are an interesting alternative connection system to bolted ones. Adding clamps (made of steel or plywood) to the outer circumference of the culm wall increases the load capacity of the joints through friction contact and improving force distribution [28].

Hubs are node-like connecting members with radially oriented elements at angles, used for geodesic dome construction. The hubs can be from different materials (e.g., steel, PVC) or connection technologies. Some hubs have pipe connector ends embedded inside each culm and then bolted [29, 30]; other hubs are with steel brackets or rods inserted into the bamboo culms and firmly anchored (Richard et al. 2017), [30].

2.3 Foundations and Plinths

In the last two decades, many innovative ways have been developed to enhance the structure stability and firmness at the foundation level, using concrete and steel [31]. In Ref. [32], the bamboo columns are embedded in sand-packed bags or buckets, which allow them to progressively sink into the sand, thus enhancing the foundational constraint. Such approach is suitable for lightweight structures, such as pavilions. Precast concrete plinths (usually in frustum form, see Fig. 1) are laid on the ground to support each column unit [33]. In heavy bamboo structures, resting the plinth and foundation upon hard surfaces such as bedrock, concrete or compacted soil is required along with laying a concrete slab or strip foundation (of concrete or brick) [34].

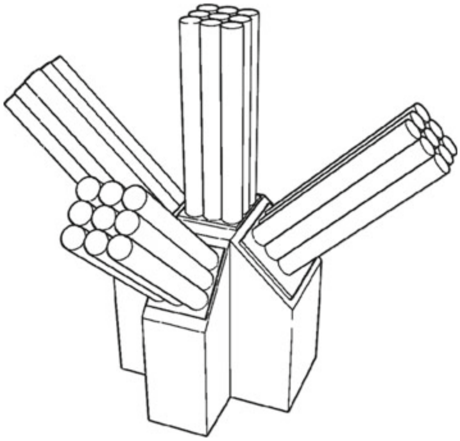


Fig. 1 Bundled bamboo culms branching out from a raised concrete plinth

3 Structural Systems and Forms

3.1 Structural Components: Columns, Bearing Walls, Floors and Roofs

Bamboo culms can act as structural column when stood up individually on a short center-to-center distances [34, 35]. However, in modern bamboo structure, multiple bamboo culms in bundled and V-shaped configurations [32] have been used to form bamboo culms, with longer spans and loads. Bundled bamboo columns can be configured in a vertically upright position [35–37], curved [38], splayed out at various angles and form [39–42], in fusiform shape, twisted cylinder, or a combination of them [32] (Figs. 2 and 3).

As for bearing walls, one traditional but effective lightweight load-bearing bamboo wall is bahareque system; it is a composite bamboo-framed wall with bamboo strips, chicken wire, adhesive materials such as soil–cement or mortar cement used for filling and plastering the wall [43].

Bamboo has also been used in flooring applications of upper levels in modern bahareque system housing [43]. In this system, bamboo culms with large diameters are used as secondary beams (joists), woven bamboo mats coated with cement mortar for floor finishes.

Round bamboo has been also successfully used as a main structural component in many advanced pedestrian bridges. Using pre-tensioned bamboo arches for setting camber is the key for constructing bamboo bridges [44].

Thanks to the advantages offered by its high strength-to-weight ratio, bamboo has been considered as potentially valuable material for load-bearing roof systems (e.g., truss, arched and dome) when operatively interconnected [45]. Vengala et al. [33] have demonstrated a good example of bamboo truss with connections of bamboo plates to reduce shearing and splitting risk. In an exhaustive study on curved bamboo

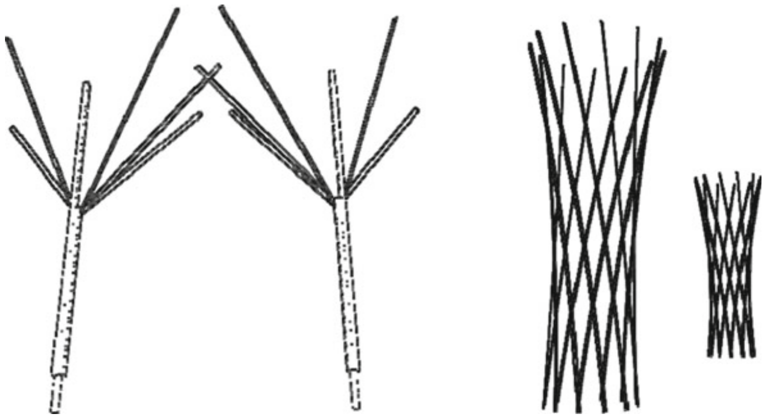


Fig. 2 Two different bamboo column configurations: (left) tree-like bamboo columns and (right) bamboo column with spiral base

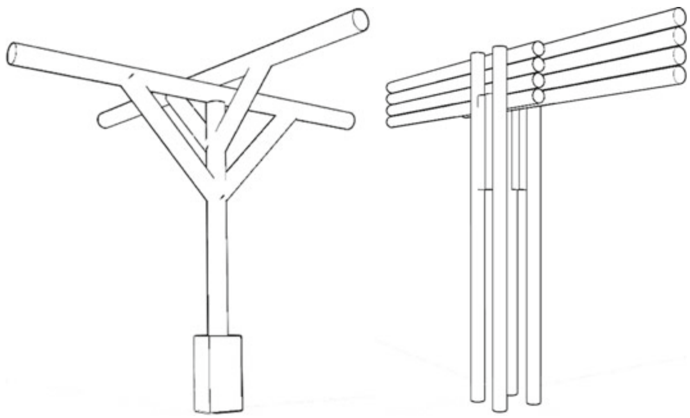


Fig. 3 Bamboo columns and beams: (left) tree-like knee-bracing, (right) configuration of bamboo columns and beams [37]

members by Tahmasebinia et al. [22], arched bamboo structures such as barrel structures with cross-over design used less bamboo culms and provided greater load carrying capacity than the straight arrangement of the arches.

3.2 Mainstream Structural Forms: Form-Active Structures

Form-active structures are subject to pure tensile (e.g. cables and membranes) or compressive (arches) external loading, without shear or bending moments. Therefore, bamboo culm could hold particular promise for this structural families due

Fig. 4 Cable-stayed bamboo cantilever, toll gate in Armenia, Colombia. Photo by: Forgemind ArchiMedia [48]

to its considerable tensile and compressive strength. In this context, Stamm [46], used bamboo culms effectively in construction of the Bali Bridge, composed of two bamboo arches linked together by steel bolts and bamboo-made dowels.

Bamboo-cable composite by Fu et al. [47] is proposed and demonstrated as a favorable application of bamboo in cable structures. The Páez Bridges, the Cucuta Bridge are another successful cable structures developed by Stamm [46], in which bamboo culms play as tensile member. Moreover, bamboo culms have been used effectively in cable-stayed cantilevers of the toll gate structure in Armenia, Colombia [48] (Fig. 4).

With the developments in connections, a number of aesthetic bamboo residential buildings have been constructed worldwide [37, 49]. Energy Efficient Bamboo House [50] is a two-storey bamboo framed house on stilts with "industrialized construction system", using novel aluminum connection system whereby structural bamboo components can be detached and replaced (Fig. 5).

4 Concluding Remarks

Raw bamboo culm is receiving new appreciation as an alternative material for construction today; according to the literature, unprocessed (or minimally processed) bamboo culm has advantages of high strength-to-weight ratio and flexibility, while being characterized by the least level of energy and pollution intensity. In view of this, many researchers and construction practitioners have been making great efforts to identify and develop reliable and effective approaches and strategies to construct with bamboo culms, in recent three decades.

Following this, a spectacular progress has been made in bamboo construction during this short time, bamboo culm material has shown an extensive scope of structural applications in modern construction. Bamboo culms have been adopted effectively as tensile and compressive load supports in different structural systems such as

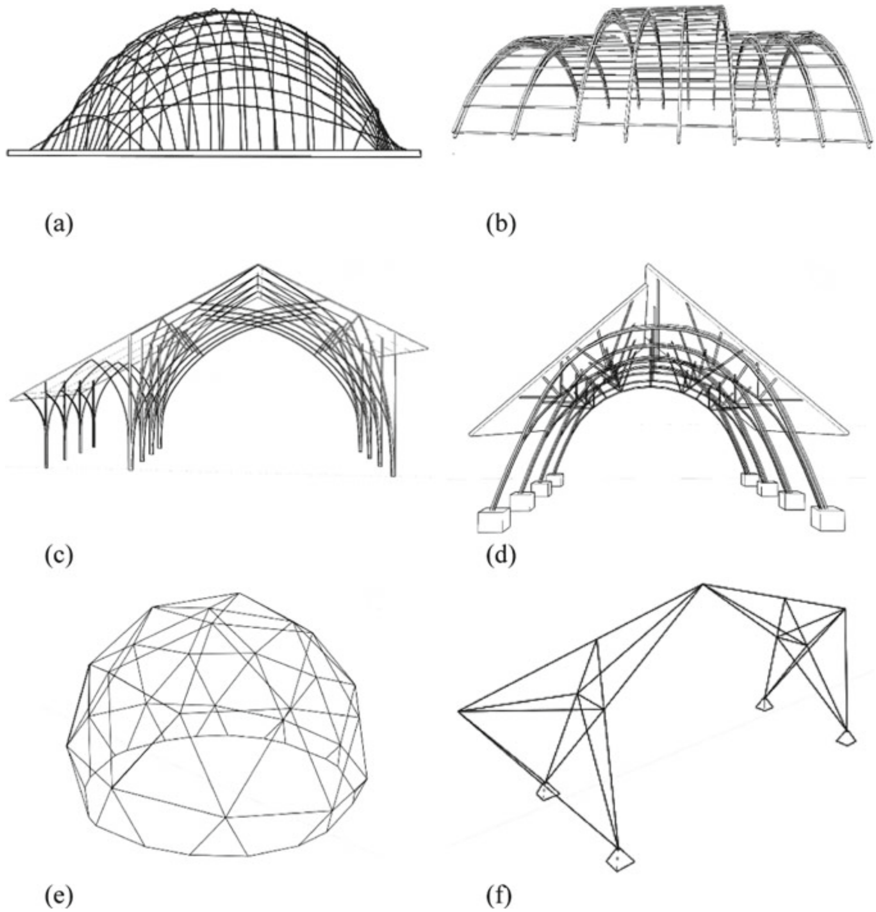
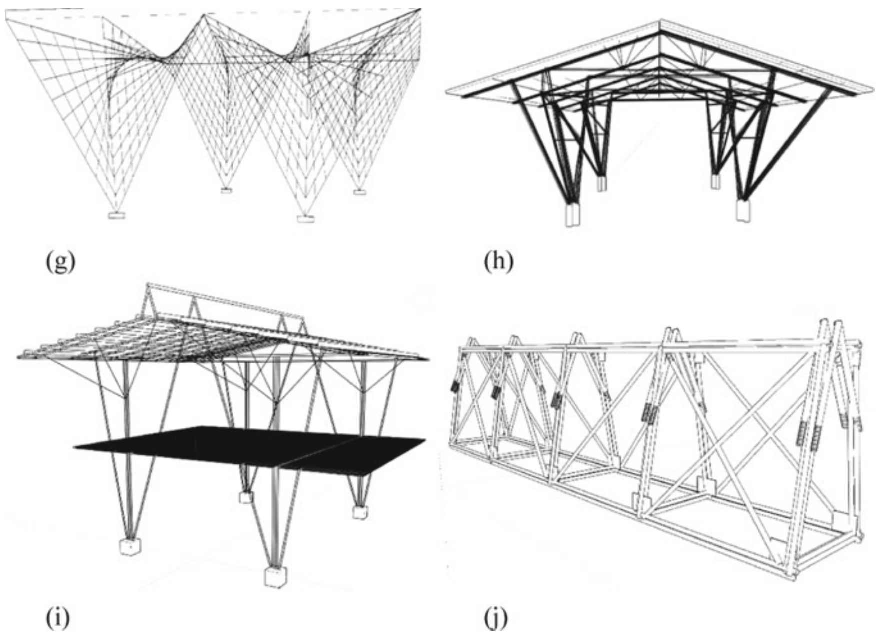


Fig. 5 Selected structural systems and their forms in round bamboo culm: **a** bamboo gridshell on a square basis [51], **b** actively bent bamboo culms spanning large distances in arched structure in INBAR pavilion [3], **c** pretensioned bamboo culms forming a vault structures with pitched roof in Naman Conference Hall [52], **d** arched bamboo trusses used in Agricultural Teaching Center (CLA, n/a), **e** bamboo geodesic dome, **f** self-standing bamboo space structure [53], **g** form-active hyperbolic shell structure in 'vinata bamboo pavilion' [54], **h** cable-stayed truss beams and sloped bamboo columns in Nu Tenka Pa' Ki—Demonstrative Bamboo Farm, **i** a two-storey structure with sloped and branching columns, **j** flat bamboo truss footbridge [55]



(g) (h) (i) (j)

Fig. 5 (continued)

trusses, space and frame structures. In addition to this, having high modulus of elasticity and a tubular structure, bamboo material can smoothly adapt to be prestressed and employed in active bending structures such as arches and shells.

A significant part of the progress made in bamboo construction is due to the advanced methods and technologies adopted in bamboo construction in the evolution of the concept of constructing with bamboo.

Introducing digital form-finding and analysis into the design procedure with an emphasis on physical modelling, has enabled the designers to achieve functional structures and highly sophisticated forms, as well as controlling their realization.

Also noticeable is the advancement made in bamboo joints to improve the behavior of bamboo structures, their stability, forms. Depending on the bamboo structural system and loads, either traditional or innovative joint technologies, or blending of both may be employed. However, the existing joints have been criticized for not being capable of meeting the needs for the high load bearing capacity of the connections with economical operation; on the other hand, more research is to be undertaken to amend adverse characteristics of bamboo culm such as brittleness with appropriate joint design [23].

With bamboo culm structures becoming more accepted internationally especially as economical and environmentally friendly alternatives for conventional building materials, a key step towards effective development in this field is to design and produce the connecting elements (joints) that are cost-effective, readily available and easy-to-operate, while adding stiffness to bamboo culm elements and whole structure.

References

1. Hisham, H.N., S. Othman, H. Rokiah, M. A. Latif, S. Ani, and M.M. Tamizi. 2006. Characterization of bamboo Gigantochloa scortechinii at different ages. *Journal of Tropical Forest Science* 236–242.
2. Sharma, B., and A. van der Vegte. 2020. Engineered bamboo for structural applications. In *Nonconventional and vernacular construction materials*, 597–623. Elsevier.
3. INBAR. 2019. INBAR pavilion architect Mauricio Cardenas Laverde. Retrieved from https://www.inbar.int/inbar-pavilion-architect-mauricio-cardenas-laverde.
4. Das, P., K. Chaaruchandra, P. Sudhakar, and S. Satya. 2012. Traditional bamboo houses of north-eastern region: A field study of Assam and Mizoram. *Key Engineering Materials*. https://doi.org/10.4028/www.scientific.net/KEM.517.197.
5. García, B., C. Preciado, M. Bedoya, and O. Mendoza. 2019. Mechanical characterization of *h* and Guadua bamboo. In *MATEC Web of Conferences*, eds. C. Chastre, and P. Mendonça, 303, 03002. https://doi.org/10.1051/matecconf/201930303002.
6. Deng, J., F. Chen, G. Wang, and W. Zhang. 2016. Variation of parallel-to-grain compression and shearing properties in Moso bamboo culm (Phyllostachys pubescens). *BioResources* 11: 1784–1795.
7. Yu, H.Q., Z.H. Jiang, C.Y. Hse, and T.F. Shupe. 2008. Selected physical and mechanical properties of Moso Bamboo (Phyllostachys pubescens). *Journal of Tropical Forest Science* 6.
8. Schneider, N., W. Pang, M. Gu. 2014. Application of bamboo for flexural and shear reinforcement in concrete beams. In Structures Congress 2014, 1025–1035. Boston, Massachusetts, United States: American Society of Civil Engineers. https://doi.org/10.1061/9780784413357.091.
9. Molari, L., L. Mentrasti, and M. Fabiani. 2020. Mechanical characterization of five species of Italian bamboo. *Structures* 24: 59–72. https://doi.org/10.1016/j.istruc.2019.12.022.
10. Akinbade, Y., K.A. Harries, C.V. Flower, I. Nettleship, C. Papadopoulos, and S. Platt. 2019. Through-culm wall mechanical behaviour of bamboo. *Construction and Building Materials* 216: 485–495.
11. Awalluddin, D., M.A. Mohd Ariffin, M.H. Osman, M.W. Hussin, M.A. Ismail, H.-S. Lee, and N.H. Abdul Shukor Lim. (2017). Mechanical properties of different bamboo species. In *MATEC Web of Conferences*, eds. J.-W. Park, H. Ay Lie, H. Hardjasaputra, P. Thayaalan, 138, 01024. https://doi.org/10.1051/matecconf/201713801024.
12. Kamath, A.V. 2013. Digitally designed architectural form-built using craft-based fabrication–weaving a complex surface as a bamboo reticulated shell. In Proceedings of the 18th international conference on computer-aided architectural design research in Asia CAADRIA, 623–632. Singapore.
13. Seixas, M., J. Bina, P. Stoffel, J.L. Ripper, L.E. Moreira, and K. Ghavami. 2017. Active bending and tensile pantographic bamboo hybrid amphitheater structure. *International Association for Shell and Spatial Structures (IASS)* 58: 239–252. https://doi.org/10.20898/j.iass.2017.193.872.
14. Crolla, K. 2018. Bending bamboo rules: Beyond century-old typologies. *Journal of Architectural Education* 72: 135–145.

15. Seixas, M.A., J.L. Ripper, and K. Ghavami. 2015. Construction of mobile bamboo dome covered with textile canvas. In *16th Non conventional building material and technologies international conference*, Winnipeg, Canadá.
16. Seixas, M., L.E. Moreira, J. Bina, and J.L. Ripper. 2018. Design and analysis of a self-supporting bamboo roof structure applying flexible connections. In *Proceedings of IASS annual symposia 2018*, 1–9. International Association for Shell and Spatial Structures (IASS).
17. Michiels, T., L. Lu, R. Archer, S. Adriaenssens, and G. Tresserra. 2017. Design of three hypar roofs made of Guadua bamboo. *Journal of the International Association for Shell and Spatial Structures* 58: 95–104.
18. Panagoulia, E., and S. Schleicher. 2016. Bending-active structures a case study for an Office Chaise Lounge.
19. Crolla, K., and A. Fingrut. 2016. Protocol of error: The design and construction of a bending-active gridshell from natural bamboo.
20. Hansen, L.H., and S. Kim. 2016. 'COCOON': A bamboo building with integration of digital design and low-tech construction. In *International conference on structures and architecture.*
21. Ho, G.W.-M., and M. Fong. 2018. Design and construction of curved bamboo structure. In *Ninth international conference on advances in steel structures*. Hong Kong, China: The Hong Kong Institute of Steel Construction.
22. Tahmasebinia, F., R. McDouga, S. Sepasgozar, E. Abberton, G.H. Joung, M.P. Joya, S.M.E. Sepasgozar, and F.A. Marroquin. 2020. Development of preliminary curved bamboo member design guidelines through finite element analysis. *Sustainability* 12: 822. https://doi.org/10.3390/su12030822.
23. Hong, C., H. Li, R. Lorenzo, G. Wu, I. Corbi, O. Corbi, Z. Xiong, D. Yang, and H. Zhang. 2019. Review on Connections for Original Bamboo Structures. *Journal of Renewable Materials* 7: 713–730. https://doi.org/10.32604/jrm.2019.07647.
24. Sonar, I.P., and V.R. Siddhaye. 2009. Theoretical and experimental investigation on single and double bolted bamboo joint under axial tension. *Journal of Structural Engineering* 36.
25. Hu, H., J. Yang, F.L. Wang, and Y.M. Zhang. 2018. Mechanical properties of bolted joints in prefabricated round bamboo structures. *Journal of Forestry Engineering* 3: 128–135.
26. Tan, G.Y., and L. Yang. 2014. *Tectonics of bamboo.* Nanjing: Southeast University Press.
27. Moreira, L.E., and K. Ghavami. 2012. Limits states analysis for bamboo pin connections. *Key Engineering Materials* 517, 3–12.
28. Masdar, A., B. Suhendro, S. Siswosukarto, and D. Sulistyo. 2015. The study of wooden clamps for strengthening of connection on bamboo truss structure. *Jurnal Teknologi* 72
29. Vahanvati, M. (2015). The challenge of connecting bamboo. In *10th World Bamboo Congress*, Damyang.
30. Wang, T.-H., O. Espinosa Trujillo, W.-S. Chang, and B. Deng. 2017. Encoding bamboo's nature for freeform structure design. *International Journal of Architectural Computing* 15: 169–182. https://doi.org/10.1177/1478077117714943.
31. Correal, J.F. 2016. Bamboo design and construction. In *Nonconventional and vernacular construction materials*, eds. K.A. Harries, B. Sharma, 393–431. Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100038-0.00014-7.
32. Minke, G. 2012. *Building with bamboo: Design and technology of a sustainable architecture.* Walter de Gruyter.
33. Vengala, J., H.N. Jagadeesh, and C.N. Pandey. 2008. Development of bamboo structure in India. In *Modern bamboo structures*, 63–76. CRC Press. https://doi.org/10.1201/9780203888926-11.
34. Jayanetti, D.L., and P.R. Follett. 2008. Bamboo in construction. In *Modern bamboo structures*, 35–44. CRC Press.
35. Paudel, S. K. (2008). Engineered bamboo as a building material. In *Modern bamboo structures*, 45–52. CRC Press.
36. House, E.E. 2017. Energy Efficient Bamboo House/Studio Cardenas Conscious Design. Retrieved from http://www.archdaily.com/868926/energy-efficient-bamboo-house-studio-cardenas-conscious-design.

37. Architects, V. 2014. Son La Restaurant/VTN Architects. Retrieved 08 Apr 2020, from ArchDaily: https://www.archdaily.com/559125/son-la-restaurant-vo-trong-nghia-architects.
38. Nurdiah, E.A. 2016. The potential of bamboo as building material in organic shaped buildings. *Procedia - Social and Behavioral Sciences* 216: 30–38. https://doi.org/10.1016/j.sbspro.2015.12.004.
39. Supreedee, R. 2015. *Research, education, design in Thai bamboo architecture*. Damyang: Curran Associates Inc.
40. Markham, D. 2019. *Meet the woman building stunning sustainable homes from bamboo*. Retrieved from https://www.treehugger.com/green-architecture/meet-woman-building-stunning-sustainable-homes-bamboo.html.
41. Schröder, S. 2019. *The Reality about building with bamboo*. Retrieved from https://www.guaduabamboo.com/construction/the-reality-about-building-with-bamboo.
42. Hudson, D. 2012. *PT bamboo pure: Green school*, Bali. Retrieved from https://www.designboom.com/architecture/pt-bamboo-pure-green-school-bali/.
43. Kaminski, S., A. Lawrence, and D. Trujillo. 2016 Design guide for engineered bahareque housing. In *INBAR–International network for bamboo and rattan*, Beijing, China.
44. Carmiol-Umaña, V. 2016. Guadua bamboo in pedestrian bridges. *Revista Tecnología en Marcha* 29: 3–13.
45. Syeda, A., B.J. Shrujal, and J. Kumar. 2014. A case study on bamboo as green building material. *International Journal of Engineering and Advanced Technology* 4: 78–82.
46. Stamm, J. 2009. Seven concepts to build a bamboo bridge. *Proceings of VIII World Bamboo Congress ISSN* 2150: 70–100.
47. Fu, Y., L. Hu, Y. Hu, and X. He. (2014). Study on the innovative application of bamboo-cable composite structures. UIA2014 Durban architecture otherwhere.
48. Sävfors, I. 2020. Echo-building. Retrieved 8 Apr 2020, from Saevfors Consulting: http://www.saevfors.se/Eco_Building.html.
49. Griffiths. (2014). *Low-cost Ecuador house built with rainforest wood and bamboo*. Retrieved from https://www.dezeen.com/2014/12/14/convento-house-enrique-mora-alvarado-bamboo-low-cost-ecuador/.
50. Laverde, M.C. 2016. *Energy efficient bamboo house*. Retrieved from https://www.studiocardenas.it/index.php/en/rainwater/32-thermal-control/148-energy-efficient-bamboo-house.
51. Correia de Melo, J.V., J.L. Ripper, and L.E. Moreira. 2013. Development of bamboo structures based on minimal surfaces and natural formations. In *Proceedings of the IASS annual symposium: Beyond the limit of man*.
52. VTN Architects. 2016. *Naman Conference Hall*. Retrieved from VTN Architects.
53. Moreira, L.E., M. Seixas, J. Bina, and J.L. Ripper. 2017. Self-supporting bamboo space structure with flexible joints. In *Proceedings of the 17th IC NOCMAT*, Mexico.
54. Barandy, K. (2019). *VTN architects introduces the hyperbolic vinata bamboo pavilion to urban Hanoi*. Retrieved from Deisgnboom: https://www.designboom.com/architecture/vtn-architects-vinata-bamboo-pavilion-01-17-19/.
55. Paraskeva, T., N.P.N. Pradhan, C.D. Stoura, and E.G. Dimitrakopoulos. 2019. Monotonic loading testing and characterization of new multi-full-culm bamboo to steel connections. *Construction and Building Materials*, 210, 473–483.
56. 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.