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STRUCTURAL BAMBOO CULMS IN THE EUROPEAN REGULATORY CONTEXT: TOWARDS A BAMBOO ARCHITECTURE

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Abstract
Introduction: Existing international standards and national building codes for structural bamboo culms provide sufficient information to safely use bamboo culms as a structural material in Europe. **Methods:** This paper analyses the literature related to the characterization, performance, and standardization of structural bamboo culms, as well as the literature on structural building codes — including national codes that already address structural bamboo culms — in order to address whether the current European regulatory context permits their use. **Results:** Despite the need for design guides related to fire safety, structural bamboo culms are suitable within the European regulatory context. This is because the structural Eurocodes and other regulatory texts that coexist with them (e.g., the Spanish 'Código Técnico de la Edificación') are performance-based. Building fire safety is incorporated into building codes through a combination of passive and active features, such as fire-rated building elements, appropriate means of egress, and fire detection and suppression systems, among others, allowing the implementation of bamboo culms as a structural material. **Discussion:** Despite the research still needed to better understand bamboo as a building material, structural bamboo culms are legally permitted within the current European building regulatory context, even as a permanent building structure.

Keywords: bamboo; European standards; structural bamboo standards; structural design; codes.

Introduction

Bamboo is a crucial partner for human development. This is especially true in times of global warming due to bamboo's carbon sequestration performance, as it is becoming increasingly urgent to find alternatives to mainstream materials such as plastic or cement, whose environmental impact can no longer be sustained at the current rate — particularly considering the building industry's carbon emissions. The President of the European Commission, Ursula von der Leyen, explicitly mentioned bamboo as a key material in the European Green Deal (Von der Leyen, 2020).

Over the last decades, in experimental applications (mostly temporary structures) as well as in permanent structures, bamboo culms used as structural elements have demonstrated that the true potential of this material has yet to be fully realized. As a natural material that has not been researched as extensively as industrial materials, there is still immense research ahead to better understand bamboo culms as a structural material. This is particularly relevant in the current global scenario, especially when supposedly well-informed reports — such as the one published by the United Nations Environment Programme (UNEP, 2023) titled 'Building Materials and the Climate: Constructing a New Future' — mention bamboo only as a fully industrialized product (with associated energy consumption and carbon emissions). In contrast, bamboo culms are worth considering even for structural purposes. This paper addresses the crucial question of whether it is legally possible to build with structural bamboo culms within the European regulatory context.

Materials and Methods

This research traces the origins and approaches to building standardization and regulation, as well as the path followed so far to standardize structural bamboo culms. Its main goal is not to identify legal voids where bamboo culms might be used structurally in Europe, but rather to ascertain whether the technical feasibility required to rely on structural bamboo culms exists — to the same extent as for mainstream materials accepted and used within the current European regulatory context, such as steel, concrete, or timber.

The main methods used in this research are descriptive (exposing characteristics of the phenomenon studied) and deductive (moving from general logical reasoning to a concrete fact). The method used to draw conclusions from a set of principles is therefore a logical one. The chosen approach consists of a critical analysis of available literature on the characterization, performance, and standardization of structural bamboo culms, combined with a comparative analysis of building codes for structural design, as well as national codes that already incorporate structural bamboo culms.

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Results and Discussion

Standards before the Industrial Revolution

There is archaeological evidence of measuring instruments or measurement standards dating back around five thousand years (Moro Piñeiro, 2020). However, it is only during the last century and a half — first with electricity and later with the automotive industry — that these technical advances have been applied in fields other than the military. There is, in fact, an intimate relationship between standardization and the birth and rise of civilizations, from Mesopotamia to the Western European empires. As Lelgemann (2004) states: “It is of utmost importance to recognize the fact that (nearly) all ancient buildings and towns are established according to an obviously standardized set of precise non-metric ancient length units”.

Geometry and structure are intrinsically related, as Eduardo Torroja pointed out in such a poetic manner. Most methods used throughout history to build as safely as possible in any given period are unknown. However, written records aimed at anticipating material performance — dating from the dawn of the scientific revolution — make it possible to trace how the interrelations between geometry and mechanics have been approached, later allowing codification in standards and norms.

According to Cervera (1983), Leonardo da Vinci (1452–1519) — whose writings range from arithmetic, geometry, painting, perspective, architecture, statics, and mechanics to fortifications, warfare, poisons, bird flight, anatomy, optics, astronomy, and so on — also studied many of the problems considered today within the disciplines of strength of materials and structural design. He made progress building on the medieval school of Jordanus Nemorarius and his “Elementa super demonstrationem ponderum” (Elements on the Demonstrations of Weights), heirs to Euclid’s school. In Da Vinci’s work (1493), there are notes and recorded experiments on strength, tension, bending deflection, forces in arches, beam design and proportions, compression, what is now called buckling, and even soil mechanics — including both experimental and theoretical expositions.

Leonardo makes clear in his notes that there is a relationship between the length and cross-section of a given structural element, together with the load carried by the element and the distribution of that load along its length, and how the structural element ‘curves’, as shown in Fig. 1. He states (Da Vinci, 1493): “Four 4-bend beams, tied together in a beam, will bend as much as a 1-bent beam, when loaded in the middle with the same weight”.

Galileo Galilei (1564–1642), starting from the notion of strength against given stresses and considering those stresses both longitudinally and crosswise to a structural element, establishes the mathematical relationship between the two: lengthwise stress and crosswise stress (Fig. 2). The relationship is set as proportional between ‘absolute strength’ and ‘relative strength’, referring to axial stress or bending, respectively (Galileo, 1638).

It was probably the challenging issue of overcoming the purely geometrical character of the strength problem, together with the inherent difficulty of theoretically addressing the scale issue, combined with Leonardo’s practice of exploring different cross-sections by using bundles as an experimental model, that prevented him from finding relationships between the strengths of beams of different depths — although he managed to do so for different widths.

In the very same volume by Leonardo in which these studies are shown, the Codex Matritensis, there is a drawing (on page 92 of the volume, shown here in Fig. 3) of what is popularly known as ‘Leonardo’s Bridge’, which is further developed with detailed drawings of the joints in the Codex Atlanticus (Ceraldi and Russo Ermolli, 2004).

There is evidence of built examples belonging to this structural typology from several centuries before Leonardo was alive, such as a scroll painting by Zhang Zeduan depicting the ‘Qingming Festival on the River’, in which the so-called ‘Bianhe Rainbow Bridge’ in Henan Province (China) is shown. According to Yang et al. (2012), more than a hundred surviving bridges of this type exist, and the typology was inscribed on UNESCO’s Urgent Safeguarding List of Intangible Cultural Heritage in 2009. This linkage between Leonardo’s bridge and traditional timber arch bridges in China raises the question of Leonardo’s inspiration — perhaps even graphic sources — coming from the Far East. The approach of varying cross-sectional performance

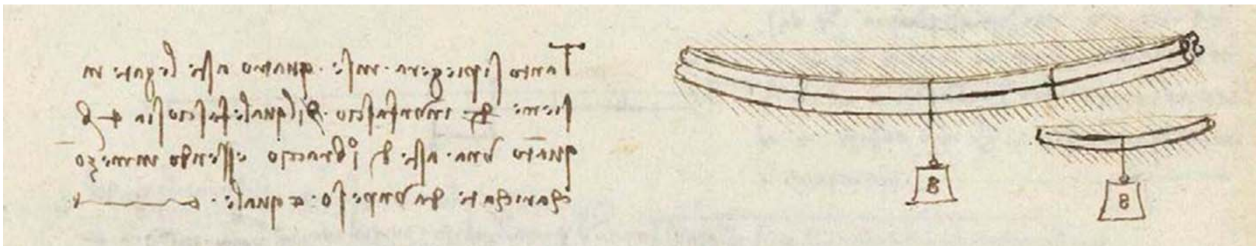

Fig. 1. Leonardo’s drawings and notes on loaded beams’ ‘curves’, as deflections. Source: Image extracted from Da Vinci, 1493

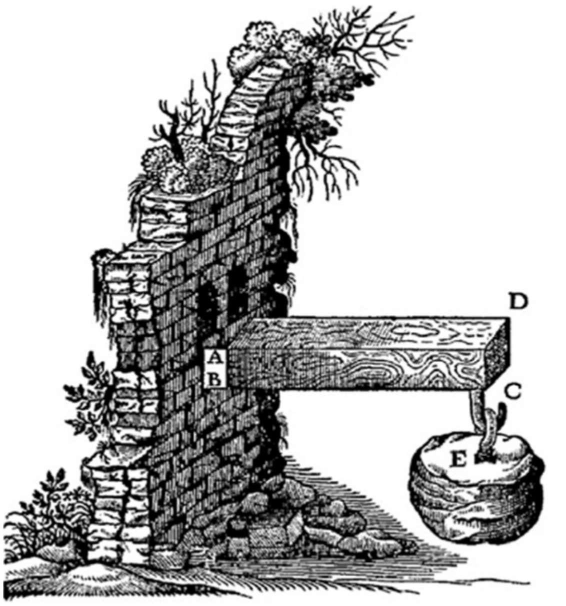

Fig. 2. Galileo’s drawing representing the relationship between ‘absolute strength’ and ‘relative strength’ of a loaded axial structural element, considering different kinds of stresses: lengthwise and crosswise. Source: Image extracted from Galilei, 1638

by adding elements to a bundle rather than using larger cross-section elements is directly related to bamboo structural design, where cross-sections are determined by the natural size of bamboo culms and the common way to increase effective sections is by adding elements to a bundle.

Resuming the development of structural design conceptualization in Europe, L.M.H. Navier represents, two centuries after Galileo, the culmination of the theory of strength of materials (despite unresolved problems related to shear stress and torque), initiating the path toward the theory of elasticity and ultimately resulting in the field of structural design.

The Industrial Revolution Onwards

Newton’s Philosophiæ Naturalis Principia Mathematica, which contains the fundamentals of infinitesimal calculus and the mathematical foundation of classical mechanics, was published in the late 1600s. Although the principles of the modern theory of elasticity also date back to the 17th century, Timoshenko’s Theory of Elasticity was published in 1934. The finite element method became common practice only in the second half of the 20th century.

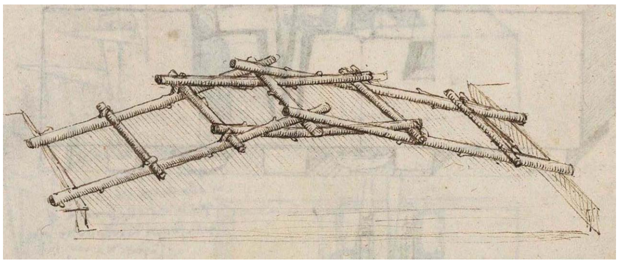

Fig. 3. Leonardo’s drawing of a bridge structure, seemingly replicating the concept behind the traditional ‘Rainbow Bridge’ structural typology in China. Source: Image extracted from Da Vinci, 1493

This demonstrates that the most powerful mathematical methods available to scientists and engineers before then had resided essentially in geometry. To provide historical perspective on the importance of geometry in structural design in the recent past, it is worth mentioning the Crystal Palace (Fig. 4), designed by Sir Joseph Paxton (1803–1865) and built between 1850 and 1851, as well as the 300-meter tower (Fig. 5) by Gustave Eiffel (1832–1923) and his company, built between 1887 and 1889.

These two structures were possible before the British Empire or the French Republic created their respective standardization committees.

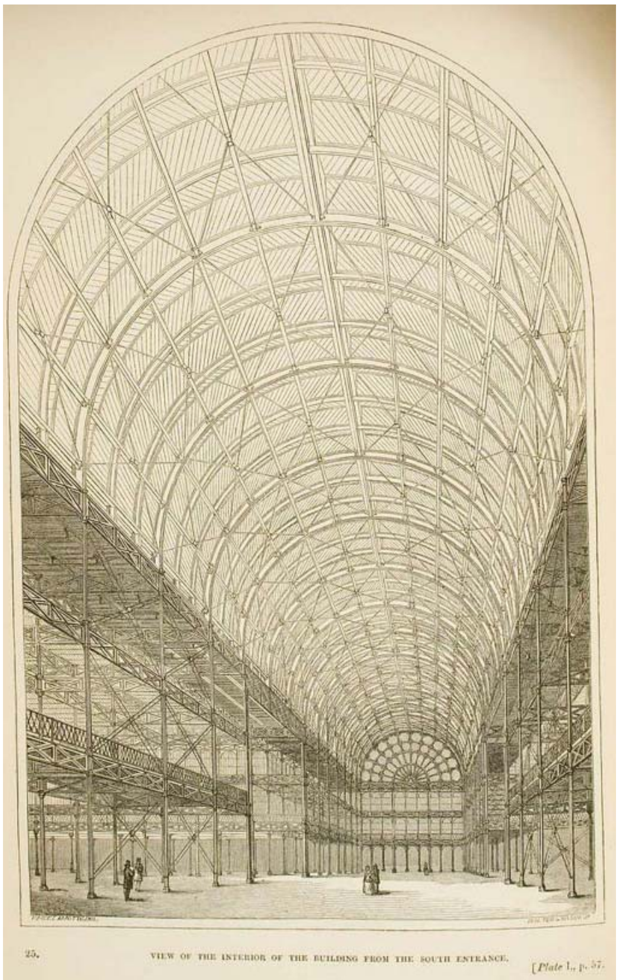

Fig. 4. Crystal Palace, built between 1850 and 1851, before the creation of the British Empire’s standardization committee, and using the Imperial British System. Source: Image extracted from the Official Descriptive and Illustrated Catalogue of the Great Exhibition 1851, Volume 1

Nevertheless, in both cases, well-developed systems of weights and measures were used: the Imperial British System and the decimal metric system (the latter had been adopted in France the same year Napoleon Bonaparte became First Consul, 1799). Both systems — the Imperial British System and the decimal metric system — are still in use today.

Frei Otto, in his comments on the history of rod structures (Dunkelberg, 1985), considers vegetal materials such as reeds, cane, or bamboo as a direct precedent of ancient stone structures, pointing out the formal similarities between the Mudhif building typology in Mesopotamia and the stone temples of Ancient Egypt. He also reminds us that successful structural inventions do not remain within individual cultural circles. On the contrary, they quickly expand, regardless of borders and boundaries. Another particularly striking example is the resemblance between tents made of bamboo culms and pagodas. In any case, the similarity — both written and spoken — between the word 'column' and the word 'culm' is evident.

There are endemic bamboo species on every continent except Europe and Antarctica. Therefore, in those countries where the Industrial Revolution sparked, there were no bamboo resources to consider as raw material in the first place. Some of those European countries governed overseas colonies where the material was available, but there was no interest in researching alien resources whose reliable, long-lasting use requires specific knowledge and care.

Fig. 5. The 300-meter tower (Eiffel Tower), built between 1887 and 1889, before the creation of any French standardization committee, and using the decimal metric system, which was implemented in France in 1799. Source: Image extracted from the Library of Congress website

Earliest Attempts to Standardize Bamboo Culms

In 1953, research requested by the Department of Housing and Urban Development was published by the U.S. Department of Agriculture. This research (McClure, 1953) is broadly focused on practical aspects of bamboo as a building material, as its title itself states: 'Bamboo as a Building Material'. It gathers built examples from Indonesia, Thailand, Colombia, Ecuador, Peru, El Salvador, and Guatemala, including some construction details regarding joinery. It is remarkable that one tenth of the volume is about 'bamboo reinforcement of concrete' — perhaps because it had been briefly researched in the 1930s and expectations for that research were still high and increasing. Perhaps it is the principle of reinforcing a brittle-failure material with a ductile one that is most surprising. About a fifth of this publication by Floyd A. McClure deals with the issue of differences among bamboo species used in housing, providing dimensional ranges for the most commonly used bamboo species as a building material, under the title 'Some Bamboos Used in Housing' (Fig. 6).

Two decades later, the Colombian architect Oscar Hidalgo-López published a book (Hidalgo-López, 1978) that includes the mechanical properties of several bamboo species cultivated in Puerto Rico, gathered by G. E. Heck in 1950, including *Guadua angustifolia, Bambusa vulgaris, Bambusa arundinacea, Bambusa tulda,* and *Dendrocalamus strictus*. The modulus of elasticity (MoE) in bending is provided for each of them, and the MoE in tension and compression parallel to the fibres is also provided for the first species, *Guadua angustifolia*.

Before then, in 1930, J. C. Espinosa tested specimens of *Bambusa spinosa* (or *Bambusa blumeana*) in bending and in compression parallel to the fibres. Espinosa concluded that a piece of bamboo with a cross-sectional diameter of 9.55 cm, when loaded at the centre over a span of 152.5 cm, could support 0.5 tons, equivalent to 5 kN. At the same time, a piece of the same cross-sectional size and 122 cm long, loaded in compression parallel to the fibres, could support 4 tons, equivalent to 40 kN. As the wall thicknesses of the tested specimens were recorded, it is possible to calculate the limit state stress of the tested sample.

Both McClure and Hidalgo-López mention earlier primary research on the mechanical properties of bamboo conducted by H. F. Meyer and B. Ekelund and published in China in 1923, but apart from being

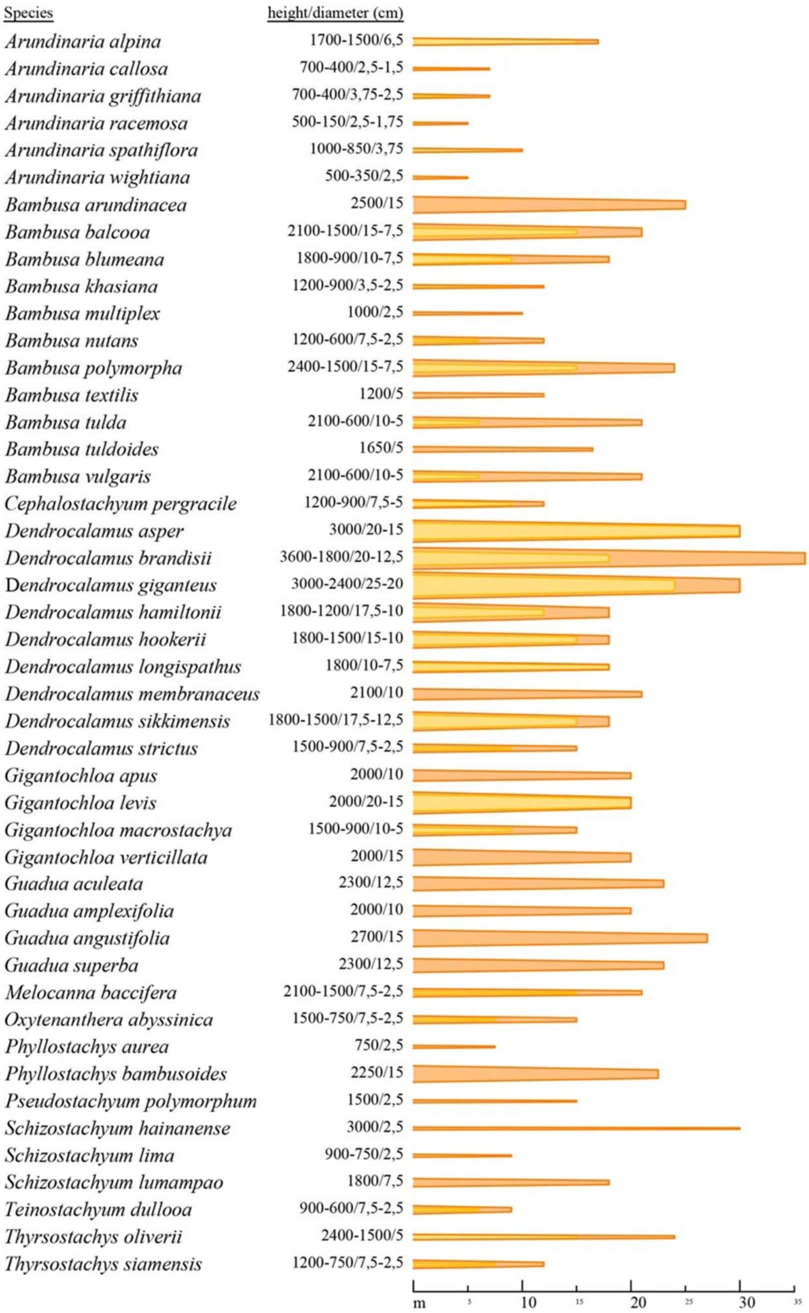

Fig. 6. Sizes of ‘some bamboos used in housing’. Own production, based on McClure (1953)

quoted (McClure, 1953; Hidalgo-López, 1978; Arce, 1993), there is no record of this publication.

The first documented systematic approach to bamboo as a structural material considering its own particular performance — starting from the microscopic level of material characterization, moving through its performance under different stresses (particularly tension and compression parallel to the fibres), and ending at the macroscopic level with structural design formulas — is Oscar Antonio Arce-Villalobos’ doctoral thesis (Arce, 1993). This represents a leap forward toward the future development of specific standards for bamboo structural design, and it is therefore among the few references considered by the earliest standards.

One of the major contributions — despite its simplicity — to the later development of bamboo structural design is the ratio of external diameter to wall thickness of culms. Arce-Villalobos provided statistical data showing that the mean thickness / diameter ratio is 0.09 with a 97 % confidence limit, while being aware of (and pointing out) the natural diversity of every bamboo culm, even within a single culm along its entire length.

Another remarkable finding by Arce-Villalobos is a correlation of 0.4 between tensile strength and density for *Bambusa blumeana*. In addition, he states that changes in cross-section and changes in MoE along bamboo culms affect their critical load, and that calculating the critical load as a function of these properties (cross-section and MoE) gives a conservative estimate if the influence of the nodes is ignored.

Research has been conducted on the existence of codes and standards for structural bamboo culms (Amede et al., 2021; Adier et al., 2023), but it makes little or confusing distinction, if any, between engineered bamboo products and structural bamboo culms. It is crucial to emphasize the distinction between these types of products because of their extremely different environmental impact: engineered bamboo products have higher carbon emissions than cement or engineered lumber (Xiaoxiao et al., 2022), whereas structural bamboo culms may even have a positive environmental impact in terms of carbon sequestration and embodied energy if harvested regularly and at the proper age, before becoming over-mature.

In addition, from a socio-economic perspective, the transformation process from a living plant to a building product is much more accessible for ‘structural bamboo culms’ than for ‘structural engineered bamboo’, because the former requires mostly labour, while the latter requires machinery and adhesive products. There is increasing interest from authorities and stakeholders in including bamboo culms in building codes and standards, both national and international.

The first code on bamboo culms dates back only to 2000. It was titled AC162 — Acceptance Criteria for Structural Bamboo. It was published in California and was developed by the International Code Council of the United States of America. As described in the section below, the Colombian code on structural bamboo (ICONTEC, 2010) set a milestone that has not been surpassed in scope and depth to date.

Table 1. **Allowable design stresses (moisture content = 12 %). Source: ICONTEC, 2010 *Internodes filled with cement**

Stress	F_i (MPa)
Bending F_b	15
Tension F_t	18
Compression, parallel F_c	14
Compression, perpendicular F_p*	1.4
Shear F_v	1.2

Table 2. **Modulus of Elasticity. Source: ICONTEC, 2010**

Modulus	E_i (MPa)
Average $E_{0.5}$	9,500
5th percentile $E_{0.05}$	7,500
Minimum $E_{\min}$	4,000

Now, 25 years after the publication of the first code in California and 15 years after the Colombian one was approved, ISO standards for bamboo culms and for engineered bamboo products are available (these products are beyond the scope of this paper). National codes that specifically include structural bamboo culms exist in Colombia, Ecuador (INEN, 2011), Peru (ICG, 2012), and India (BIS, 2018).

The Pioneering Building Code of Colombia

In 2010, the Colombian code for seismic-resistant structures, NSR-10 (ICONTEC, 2010), was approved. It includes a specific chapter on bamboo structures built with the most common species in Colombia, Guadua angustifolia Kunth, or simply Guadua. NSR-10 utilizes allowable stress design (ASD), based on previous characterization of Guadua. Therefore, NSR-10 is considered a precedent for applying the ASD approach, which is permitted by ISO 22156:2021 in combination with ISO 22157:2019, using Guadua as the subject species. Moreover, NSR-10 served as the reference for Ecuador (INEN, 2011) and Peru (ICG, 2012) when adopting their own national structural bamboo codes.

The allowable design stresses and the MoE included in NSR-10 for Guadua angustifolia Kunth are shown in Table 1 (note the difference in orders of magnitude between bending, tension, and compression parallel on the one hand, and compression perpendicular and shear on the other) and in Table 2, respectively.

Due to the anisotropic nature and heterogeneity of this organic material, safety coefficients are defined within the code to obtain the ‘modified service stress’ from the ‘service stress’ for each type of stress. Some of these coefficients are applied depending on the stress type (bending, shear, compression parallel), while others are applied in general, such as:

- load duration (ranging from 0.9 for permanent dead loads to 2.0 for impact loads);
- moisture content (ranging from 1 to 0.7);
- temperature (ranging from 1 to 0.4);
- combined action (1.1 when four or more elements work together and are located less than 0.5 m from each other).

The most restrictive coefficient is the one related to service temperature: it is 0.4 when the expected room temperature is between 52 °C and 65 °C. Above this temperature, the use of structural bamboo culms is not recommended. Although other organic materials may be more severely affected by long-term loads, bamboo culms experience a serious drop in mechanical performance due to high room temperatures more than due to any other condition.

ISO Standards Related to Structural Bamboo Culms

In 2004, the first edition of ISO standards on bamboo from a structural perspective was published. It consisted of two volumes: ISO 22156:2004 — Bamboo — Structural design and ISO 22157:2004 — Bamboo — Determination of physical and mechanical properties. Despite being the first international attempt to address bamboo culms as a structural material and to develop a structural design standard for them while providing guidelines for characterizing particular bamboo species, it was still not possible to perform a proper structural design for any type of building structure based solely on those ISO standards.

In 2013, the revision procedure began, resulting in a suite of material and design standards for full-culm bamboo: ISO 19624:2018 — Bamboo structures — Grading of bamboo culms, ISO 22157:2019 — Bamboo structures — Determination of physical and mechanical properties of bamboo, and ISO 22156:2021 — Bamboo structures — Bamboo culms — Structural design. The adoption of widespread methods familiar to engineers has overcome the previously existing obstacles to using structural bamboo culms in construction. Two approaches are permitted by ISO 22156:2021: allowable load-bearing capacity design (ACD) and ASD. ACD requires the application of ISO 19624:2018 to determine the moment capacity for each grade previously assigned to members, whereas ASD is based on material properties as defined in ISO 22157:2019. The possibility of developing column axial load tables and beam flexural load tables based on the practical use of ISO 19624:2018 and ISO 22156:2021 has already been demonstrated (Harries et al., 2022).

Eurocodes and the Technical Building Code

Structural Eurocodes, which are used in most European countries, are performance-based codes. Although Eurocodes are widely adopted across European countries, in some countries they are the only regulatory texts (e.g., France and Germany), whereas in others they coexist with additional regulatory texts (e.g., Italy). Finally, there are a few countries, such as Spain, where national codes prevail over the Eurocodes. The Technical Building Code — in Spanish, “Código Técnico de la Edificación” — which is applicable in Spain, is also a performance-based code (CTE, 2022).

Therefore, in Spain as well as in the rest of Europe, a particular material or construction system does not need to be explicitly included in the code to be used in a building project, as long as a competent technician justifies that its performance fulfils the code’s requirements and provides the specifications needed to meet them. The code includes supporting documents called Basic Documents (Documentos Básicos, DB), which address mainstream practices. In the structural domain, these include documents on masonry, steel, and timber. Concrete is not included in the DB-SE because a separate complementary standard deals with it. Thus, to date, five structural materials are explicitly considered by the CTE and the Eurocodes: steel, masonry, timber, concrete, and aluminium.

In Europe, besides the temporary ZERI Pavilion at Expo Hannover 2000, there is another significant example of structural bamboo culms still standing over twenty years after completion: the Vergiate Pavilion (Vantomme et al., 2003), finished in 2003, covering 32 by 16 metres. According to Donini et al. (2022), it is feasible to design a building using structural bamboo culms in compliance with the Italian regulatory framework, as long as it is supported by the international standard on structural bamboo culms. That standard provides characteristic and design values for bamboo (as well as correction factors) while also indicating how to verify the performance of bamboo culms and their connections. Nevertheless, the need for design guides related to fire safety is evident.

Regarding Fire Safety

A critical aspect of the structural design of a building is to rate its structural performance in the event of fire. Mena et al. (2011) report a charring rate of 0.24 mm/min when bamboo is used as a finishing element and 0.20 mm/min when used as a structural element for Guadua, but these values are based on only two tests. As Correal (2020) states, building fire safety is incorporated into building codes through a combination of passive features — such as prescriptive measures for fire-rated building elements or appropriate means of egress — and active features, such as fire detection and suppression systems.

According to Gutierrez (2020), the structural fire performance of load-bearing bamboo systems must be understood before they can be used with the same level of confidence as more traditional and widely used construction materials such as concrete or steel. His experimental research found that at a temperature of 250 °C, a reduction factor of 0.1–0.2 for compressive and tensile strengths parallel to the fibres should be applied to bamboo culms, whereas the reduction factor for their MoE should be 0.7.

Gutierrez notes that the mechanical properties of bamboo culms at elevated temperatures are not available in design guidelines or scientific literature, indicating the need to include this information in future bamboo building codes and design guidelines. In the Eurocode and the CTE, the mechanical response for materials that undergo charring is defined by the charring rate, resulting in a progressive reduction of the element’s cross-section.

After conducting fire tests on load-bearing bamboo bahareque wall systems (also known as light cement-bamboo frame, LCBF) using specimens of 1050 mm × 1050 mm — first exposing the specimens to fire and then calculating the residual capacity of the walls — Salzer et al. (2016) concluded that all specimens achieved a 60-minute fire resistance rating, which was the target resistance of the study. They pointed out that the configuration of the covering was a key factor in providing sufficient protection to the structural members. In addition, a detailed assessment of the mechanical resistance of bamboo poles after fire exposure showed that initial charring after failure of the protective cover does not immediately jeopardize the load-bearing capacity of the system and could possibly be taken into account in system performance assessments. Further research is required to determine safety factors and mechanical properties for structural bamboo culms in the event of fire.

Despite the limited research carried out to assess the performance of exposed bamboo culms in fire, a 24 mm thick gypsum-based plasterboard provides a 60-minute fire resistance rating (FRR) (Kaminski et al., 2016). The document in the CTE (2022) related to the fire resistance of walls, ceilings, and doors that define fire compartments allows a 60-minute FRR for above-ground residential, educational, and administrative buildings up to 15 m tall.

Conclusions

1. The existing international standards and national building codes that include structural bamboo culms provide sufficient information to safely use bamboo culms as structural elements in Europe, given that the Structural Eurocodes and other national codes that coexist with them are performance-based.
2. This is currently limited to *Guadua angustifolia Kunth* bamboo species harvested in Colombia, due to the design values included in the Colombian structural code, NSR-10.
3. Following the ISO standards, other bamboo species — and/or specimens from other sourcing locations — may be characterized to perform structural design, resulting in long-lasting, safe structures.
4. Structural bamboo culms are legally permitted within the current European regulatory context, even as a permanent building structure.
5. As a natural resource that has not been researched as extensively as fully industrialized materials, there is an immense amount of research ahead to better understand bamboo culms as a structural material.
6. Research to better understand the mechanical performance of structural bamboo culms in the event of fire is particularly relevant for determining evidence-based safety factors.

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БАМБУКОВЫЕ СТВОЛЫ В СТРОИТЕЛЬСТВЕ В ЕВРОПЕЙСКОМ НОРМАТИВНОМ КОНТЕКСТЕ: НА ПУТИ К БАМБУКОВОЙ АРХИТЕКТУРЕ

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Аннотация

Введение: Существующие международные стандарты и национальные строительные нормы, касающиеся использования бамбуковых стволов в строительстве, предоставляют достаточно информации для безопасного использования бамбуковых стволов в качестве конструкционного материала в Европе. **Методы**: В данной статье анализируется литература, связанная с характеристиками, эксплуатационными свойствами и стандартизацией бамбуковых стволов в области строительства, а также литература по строительным нормам, включая национальные нормы, уже учитывающие использование бамбуковых стволов в строительстве, чтобы ответить на вопрос, позволяет ли текущая европейская нормативная база их использование. **Результаты**: Несмотря на необходимость в руководствах по проектированию, касающихся пожарной безопасности, строительные бамбуковые стволы являются приемлемыми в рамках европейского нормативного контекста. Это связано с тем, что европейские кодексы по строительным конструкциям и другие существующие нормативные документы (например, испанский «Технический строительный кодекс» («Código Técnico de la Edificación»)) основаны на эксплуатационных характеристиках. Требования пожарной безопасности зданий включены в строительные нормы через комбинацию пассивных и активных мер, таких как противопожарные строительные элементы, соответствующие пути эвакуации, системы обнаружения и тушения пожаров и другие, что позволяет использовать бамбуковые стволы в качестве конструкционного материала. **Обсуждение**: Несмотря на то, что исследования, необходимые для лучшего понимания бамбука как строительного материала, всё ещё актуальны, бамбуковые стволы разрешены к законному использованию в рамках текущей европейской нормативной базы в области строительства, в том числе в качестве материала для капитального строительства.

Ключевые слова: бамбук; европейские стандарты; строительные стандарты для бамбука; проектирование конструкций; нормы.