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Viability of whole-culm bamboo construction in South Africa – a preliminary assessment

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We describe literature-based research on the viability of whole-culm bamboo as a construction technology for South Africa. South Africa has one bamboo species considered suitable for construction, namely *Bambusa balcooa*, found in various parts of the country. Quantitative production figures are not currently available; however, local reports indicate that South Africa can expand its bamboo growth industry to meet any possible expected demand. Although the South African bamboo plant has not yet been evaluated in terms of its material properties, engineering design approaches and material properties from the literature indicate that this species is a viable construction material. The limitations for bamboo design and construction are not unique to South Africa but are common to countries involved in bamboo construction. Their experience in overcoming these limitations can be transferred to the use of bamboo in South Africa, making bamboo construction a potentially viable construction technology in South Africa.

Significance:

- Whole-culm bamboo can be used as a structural material in buildings and other specialised structures such as bridges, assembly halls, and the like.
- South Africa has a bamboo species that should potentially be suitable for the construction of structures that lend themselves to this type of construction.
- The information given here should allow designers, engineers and technologists to assess the viability of bamboo construction in South African situations.

Introduction

Bamboo has been used as a traditional building material in many countries for centuries, with reports of bamboo houses in China from 2000 years ago[1] and dams such as the Du Jiang Dam built during the Xia Dynasty[2]. In recent times, bamboo has been made popular by architects such as Simón Vélez (Figure 1) and Jörg Stamm, who operate mainly in Colombia. Although bamboo products, such as floorboards, are popular in South Africa, the use of whole culms in bamboo construction is, practically, not used in South Africa, despite this plant's presence in various parts of the country. In view of the need for innovative and environmentally friendly construction materials and technologies, in particular to meet South Africa's housing challenge, it is appropriate to investigate other possible viable options.

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Figure 1: Bamboo cathedral by Simón Vélez, Colombia.

A literature review to consider the use of whole-culm bamboo construction in South Africa highlighted the lack of coherent structural information regarding bamboo as a potential construction material, particularly from an engineering perspective. Although there are numerous guidelines regarding the construction of bamboo buildings and structures, these focus on construction techniques and are written predominantly by architects or building contractors. Thus, the essential structural properties and design approaches familiar to structural engineers are largely not elucidated in these publications.

Notwithstanding the above, two beneficial sources found were *Designing and Building with Bamboo*, written by Janssen[3] in conjunction with the International Network for Bamboo and Rattan (INBAR), and a series of technical instructional articles by Kaminski et al.[4-7] published in *The Structural Engineer*.

Janssen's technical report[3] collates the practical experience of engineers working with bamboo, together with research programmes into bamboo properties at that time. Aspects covered include the structure of the bamboo plant, propagation, harvesting and preservation. In addition, the mechanical properties of the bamboo culm, together with the typical design calculations required, and aspects such as bamboo connections are addressed. Furthermore, the report touches briefly on the bamboo design standards available at that time and efforts that were then being made towards an international design standard.

In collaboration with the Institution of Structural Engineers (IStructE), Kaminski et al.[4-7] published a five-part technical series on bamboo as a structural material. The series aimed to provide guidelines for the safe design of bamboo structures by collating current knowledge and best practice, based on existing published bamboo and timber design codes. The areas covered were bamboo as a plant, durability and preservation of bamboo culms, design values and equations. The fifth part on bamboo connections has not yet been published.

Information that was available on South African bamboo[8-11] did not include engineering or material properties but focused primarily on bamboo as a source for biofuel and bamboo farming for such purposes. Thus, considerable local and practical research would still be needed if bamboo construction were to become an accepted and standard construction technology in South Africa. Such research would need to establish the engineering and material properties of South African bamboo, as well as provide input towards developing a national design code for such construction.

We aimed to evaluate whether whole-culm bamboo construction is a viable construction technology for South Africa and provide critical information sourced to highlight the areas requiring further research and investigation in the South African context.

Research methodology

The research was primarily desktop in nature due to the lack of bamboo structures and bamboo construction in South Africa. A comprehensive literature review and document analysis were conducted on bamboo and bamboo construction, mostly focused on South Africa and surroundings. Limited technical data were available, and therefore information was also collected from online news articles, project reports and Internet websites of organisations such as INBAR and NBASA (National Bamboo Association of South Africa). The primary Internet search engine used was Google Scholar, using search terms such as "bamboo", "South Africa" and "Bambusa balcooa". Each document or article was reviewed and critiqued regarding the validity, reliability and applicability of the information presented. For the news articles and websites, this entailed tracing the original source of information to verify the details. Where references were provided in the reports, the original references were scrutinised to verify the information. Furthermore, the current status of the information presented was interrogated, and the sources contacted for updated details.

Due to the general lack of bamboo structures in South Africa, the only site visits conducted were to local areas of bamboo growth in the Western Cape, and to a bamboo farm in Vredendal, in the Western Cape.

Bamboo in South Africa

An assessment of bamboo resources in 2005 by the Food and Agriculture Organization (FAO) of the United Nations and INBAR, found that Africa had 7% of the world's bamboo resources[12], comprising approximately 2.7 million hectares of bamboo forest[13]. Some of the species are indigenous, being endemic due to natural processes. Others are considered introduced or naturalised species, having been brought to an area by human action or intervention. After 10 years without direct intervention by humans, introduced species may be considered to be naturalised.

South Africa has one indigenous species, namely *Thamnocalamus tessellatus* or 'bergbamboes' (Figure 2). This species is a loosely tufted bamboo that grows in dense clumps. It is used to construct gates and screens and for walking sticks, implement handles and spears.[14] It is found in the mountains of South Africa, Lesotho and Swaziland, at elevations of 1500–2000 m.

Image: SANBI[39] under licence CC-BY-NC

Figure 2: *Thamnocalamus tessellatus* – an indigenous South African bamboo species.

South Africa also has a naturalised species, namely *Bambusa balcooa*, also known as 'Giant bamboo', which is said to have been introduced into South Africa in 1653 by the Dutch East India Company.[15] This species grows in the KwaZulu-Natal, Mpumalanga, Gauteng, Eastern Cape and Western Cape Provinces (Figure 3).[16,17]

Figure 3: *Bambusa balcooa* at Canal Walk Shopping Centre, Western Cape.

Several commercial initiatives to grow bamboo have been initiated in South Africa in the past 10 years, which are described in detail by Scheba et al.[14]. Some, such as the Green Grid Beema Bamboo Project in KwaZulu-Natal (Barathi N 2020, written communication, October 20) and the pilot projects at Ndakana, Uitenhage and Chintsa by the Eastern Cape Development Corporation in the Eastern Cape, have been abandoned due to drought, land ownership disputes, community conflicts and a shortage of funds (Figure 4).[14]

One successful initiative is the Kowie Bamboo Farm, owned by EcoPlanet Bamboo Southern Africa and situated in the Eastern Cape (Figure 5a). Two bamboo species are grown on the farm[18], namely *B. balcooa*, the preferred local species, and *Oxytenanthera abyssinica*, a drought-resistant species thought to have been introduced to South Africa from Zimbabwe[15]. Although the last planting was reported to have been done in 2014, no culms have been harvested to date.

A further successful initiative is a farm called Lateral Project Solutions, based in Vredendal in the Western Cape (Figure 5b). Several bamboo species such as *Phyllostachys edulis*, *Bambusa vulgaris* and *O. abyssinica* are being grown to determine which ones adapt best to the local climate.[15] Although the plants are growing well, no findings have been published at this stage.

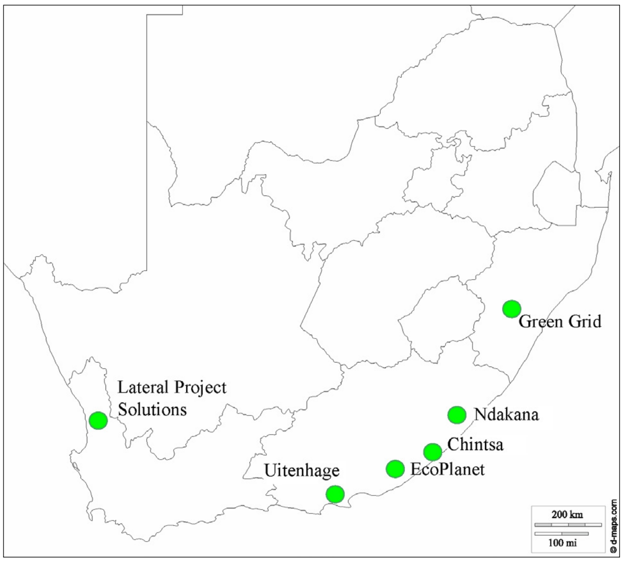

Image: ©Andreas Scheba; adapted from Scheba et al.[14] with permission

Figure 4: Map of commercial bamboo projects and activities in South Africa.

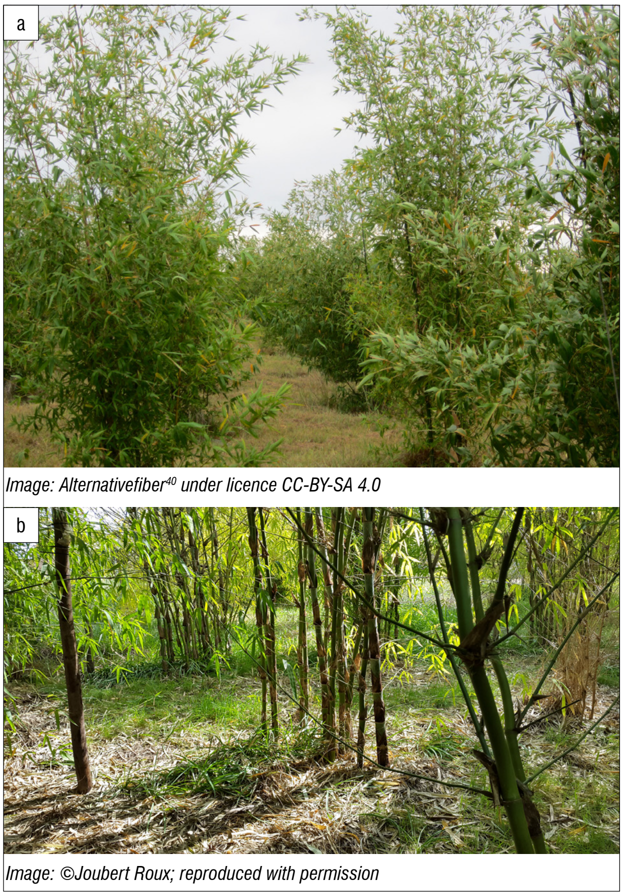

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Figure 5: (a) Kowie Bamboo Farm, Bathurst, Eastern Cape, South Africa. (b) Lateral Project Solutions Bamboo Farm, Vredendal, Western Cape, South Africa.

Thus it can be seen that certain bamboo species can grow and thrive in the South African climate, provided that they receive sufficient water and care, and could therefore be a source of construction materials.

Anatomy and growth of southern African bamboo

A bamboo plant consists of the visible stems and leaves and the underground root system. The culm or stem is the portion of the bamboo plant found above ground. The culms are generally straight and hollow and vary in size, diameter and texture, depending on the species. At particular spacings along the culm, there are transverse diaphragms or nodes, which are solid (Figure 6). These diaphragms provide a pathway for nutrients and prevent buckling and cracking of the walls by providing cross-sectional stiffness. The cells in the culm length (i.e. the internode) are oriented axially along the length of the culm, with no radial cell elements. Most internodes are hollow, although some species have solid internodes, often referred to as 'male bamboo'. Thus, in the species with hollow internodes, the only transverse connection in the culm is at the nodes or diaphragms.[3,4] The outermost skin or layer of the bamboo culm wall is covered with a waxy layer of silica, which protects the culm from water ingress.[4]

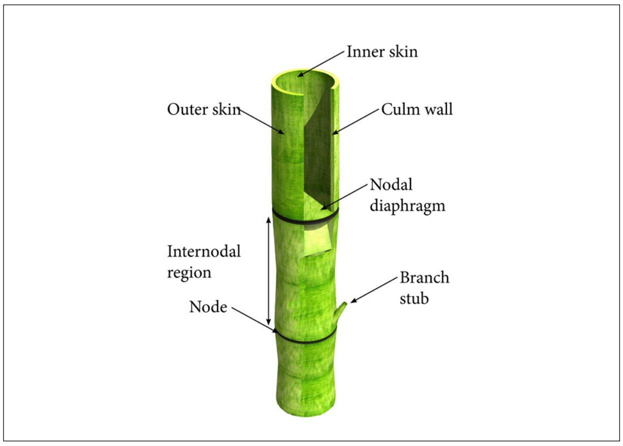

Image: ©Sebastian Kaminski[4]; reproduced with permission

Figure 6: Parts of a bamboo culm.

The macroscopic characteristics of bamboo vary along the height or length of the culm, with the culm diameter and wall thickness decreasing from the base of the plant upwards.[3] The cross-section of the culm is roughly circular to elliptical, tapering towards the top of the plant. Shorter culms taper more strongly, while longer culm lengths taper less, and as a result, these are often preferred for building purposes, as this results in straighter culms with less change in diameter.[19]

Although other bamboo species growing in South Africa could be used for structural and construction purposes, *B. balcooa* is currently considered the most suitable. This is a clumping species with sterile seeds, and as such, is not regarded as invasive. It grows to an average height of 20–30 m, with a culm diameter of 80–150 mm, a wall thickness of 25–50 mm and 200–400 mm internodal spacing.[20] Although this species reaches maturity between 5 and 8 years, as with other bamboo species, it can be harvested at 3 years of age for construction purposes.[10,14,18]

Bambusa balcooa requires approximately 5000 litres of water per year per clump[21] (irrigation or precipitation), which equates to roughly 14 litres per day. This amount is similar to the quantity of 14.5 litres per day reported by Roux (Roux J 2020, oral communication). The amount of water provided influences the growth rate. As such, Scheba et al.[14] recommended that bamboo be grown in South Africa in areas of high rainfall, such as the Eastern Cape and KwaZulu-Natal, which have a mean annual rainfall of 600–1000 mm per year.[22]

Quantitative requirements for bamboo construction in South Africa

South Africa currently imports a variety of bamboo products. In 2012, 68 t (metric tons) of raw bamboo was imported, increasing to 141 t in 2020.[23] This increase in imports indicates an increased demand for bamboo products in South Africa[14], although this is small when compared to world imports such as China, which imported 21 398 t of raw bamboo in 2020. The most common uses of bamboo in South Africa were fencing, flooring, cladding, home products such as chopping boards, and household furniture.

South Africa exported 494 t of bamboo flooring and 15.6 t of bamboo paper based articles in 2020.[23] The difference between import and export values of bamboo appears to indicate that the difference is partially made up of locally grown bamboo.

The South African Bamboo Interim Steering Committee, formed in 2012, produced a strategy document for the promotion of bamboo in South Africa.[13] Included in this document was a study done by the South African Agricultural Research Council on the potential for bamboo production in South Africa, in which possible land areas were grouped into four classifications, based on the physio-biological requirements of the plants, namely high, moderate, low and marginal. They reported that South Africa had 421 715 ha with a high potential for bamboo production, representing 0.5% of the total South Africa surface area. Of this high potential group, KwaZulu-Natal had the largest suitable area (188 023 ha), while the Western Cape had the smallest (6214 ha). It was noted in the report that this represented the potential for bamboo production and not the available land.[13]

Furthermore, 1 590 076 ha was considered moderately suitable, 2 374 967 ha was considered to have low suitability, and 4 604 471 ha was considered marginally suitable. These hectares represented 1.9%, 2.8% and 5.4% of the total surface area of South Africa, respectively. A summary is provided in Table 1.

Table 1: Potential bamboo production areas in South Africa[13]

Province	Province area (ha)	Percentage of province suitable for bamboo production[a]				Total (%)
		High	Moderate	Low	Marginal	
Eastern Cape	16 896 598	0.05	0.37	0.57	0.54	1.5
Free State	12 982 516	–	0.03	0.26	0.77	1.1
Gauteng	1 817 830	–	–	–	0.78	0.8
KwaZulu-Natal	9 435 133	0.22	1.07	1.06	0.80	3.1
Mpumalanga	7 649 471	0.17	0.32	0.76	1.16	2.4
Limpopo	12 575 396	0.04	0.06	0.10	0.84	1.0
North West	10 488 168	–	–	–	0.42	0.4
Western Cape	14 010 998	0.01	0.01	0.02	0.06	0.1
%Total RSA surface area		0.50%	1.9%	2.8%	5.4%	

[a]*Adapted from Bamboo Interim Steering Committee[13] with permission*

Based on the 2012 import information (68 t of raw bamboo), the Bamboo Steering Committee calculated that 865 ha of bamboo farming would be sufficient to produce that amount of bamboo locally, representing only 0.2% of the high potential areas, based on the assumption that the required bamboo varieties can be grown in South Africa, and that 1 ha of bamboo plantation could yield 20–40 t of bamboo per year. If the demand for bamboo increased, such as would be expected if bamboo were used as a construction material, it was estimated that utilising up to 1% of the high potential area would be sufficient to satisfy total demand. Thus, it appears that South Africa could produce sufficient bamboo locally to supply current and future bamboo needs, without the need for importing any bamboo.[13]

As yet, no figures are available as to the amount of bamboo produced locally by the various growers and nurseries. Once these figures become available, it will be possible to verify the above assumptions regarding the amount of bamboo produced and thus whether South Africa can meet the bamboo demand with locally grown bamboo.

Design and construction using South African bamboo

Many factors can affect a building project's success or failure, not all of which can be quantified. In order to ensure success, it is necessary, inter alia, to understand the limitations inherent in the chosen building material and to select the appropriate mitigations.

For design and construction using bamboo in South Africa to be successful, the structural engineering issues that arise when building with bamboo must be addressed. These can be categorised into three main areas, namely:

- Geometry and anatomy of the bamboo
- Material and engineering properties
- Analysis, design and modelling aspects

Geometry and anatomy of the bamboo

Bamboo culms do not have a regular circular shape, being closer to an ellipse. In addition, the diameter and wall thickness of the culms vary along their length, and the internodal lengths vary from base to top.

The variations in physical geometry present problems with the construction of bamboo structures. When building with steel, timber or concrete, the member sizes can be matched so that connections can take the same form and aesthetic. With bamboo members, either each connection should be unique, or connectors should be used that can be adapted to varying diameters and sizes. In addition, the culms are hollow, which results in little or no support in the middle of the culm to transfer the loads, particularly shear loads. Thus, it is recommended that bamboo members be designed to carry mainly axial loads, with shear loads applied at the nodes.[4]

As described earlier, *B. balcooa* has typical geometrical characteristics such as a culm height (internodal spacing) of 200–400 mm, culm diameter of 80–150 mm, and wall thickness of 25–50 mm. However, the actual dimensions are specific to each plant and batch of material, and would need to be determined prior to design and construction.

The curvature of the culms can also affect a structure's regularity, where the columns and beams could be slightly out of plumb. This curvature can be overcome by using a mortar or plaster overlay on the frame or walls to mask the variations, similar to the bahareque construction method.[24] Alternatively, the culms can be selected to minimise this curvature and allow the slight curvature to add to the structure's natural look.

The bamboo culms are covered with a layer of silica on the outside. Although this waxy layer protects the culm from ingress of water, it also presents a problem during construction, as the outer layer of silica on the culm walls reduces the friction of the culm surface. This condition necessitates that connection designs do not rely on the culm's frictional resistance to function, but instead assume frictionless surfaces which require positive mechanical joints.[25]

Material and engineering properties

Although engineering and material properties are not readily available for South African *B. balcooa* plants, this species grows in other parts of the world, and reports have been published on its properties. These values can be used as a guideline for South African bamboo properties. However, it is essential that the local plants are comprehensively tested to assess their specific engineering and material properties prior to any detailed structural designs. Such testing would have to build up sufficient statistical data for design calculations to achieve adequate material factors, or factors of safety.

Physical and mechanical properties

Salient physical and mechanical properties are summarised in Table 2. The variability in the quoted values can be ascribed to different testing

Table 2: Summary of *Bambusa balcooa* properties

Density (kg/m³)	Modulus of rupture[a] (MPa)	Compressive strength[b] (MPa)	Shear strength[c] (MPa)	References
783 (green)	65 (green)	47	–	Bureau of Indian Standards[26]
720–850	116–173	48–81	10–13	Naik[30]
570–740 (green) 790–850 (dried)	62–85 (green) 70–93 (dried)	39–51 (green) 51–57 (dried)	–	INBAR[20]

[a]*Measured transversely in flexure*
[b]*Measured parallel to the grain*
[c]*Measured perpendicular to the grain*

procedures and the geographical location where the plants were grown. Also, it is known that the properties of bamboo culms vary along the length of the culm as well as with the age of the culm. Details were not available regarding the testing procedures, and thus it can be assumed that the variable values result from the factors mentioned above.

It should be noted that the properties extracted from the Indian National Building Code[26], as indicated in Table 2, are results obtained from tests on culms of 6 m lengths and are not the properties recommended for design. This code recommends using a safety factor of 4 for flexure and 3.5 for compression. This would result in design stresses of 16 MPa and 13 MPa for the modulus of rupture and maximum compressive strength, respectively.[26]

The International Organization for Standardization (ISO) released two standards for bamboo design in 2004, subsequently updated in 2012, namely ISO 22156:2004 – Bamboo structural design[27] and ISO 22157:2004 – Determination of physical and mechanical properties of bamboo[28,29]. Although these standards do not provide design values or properties, they provide guidance for design procedures.

Both Janssen[3] and the ISO design standard[27] recommend using a safety factor of 2.25 to calculate allowable design stresses. It is unclear why the Indian code recommends a higher safety factor, but this could be based on the expected reliability and variability of the properties found in the local species of bamboo.

Janssen[3] suggested rule-of-thumb ratios to determine properties of bamboo culms based on their density, to be used in preliminary designs (Table 3). Using a density of 783 kg/m³, as indicated by the Bureau of Indian Standards in Table 2, the ratios provide theoretical ultimate stress values of 110 MPa for the modulus of rupture and 74 MPa for the compressive strength. Applying a safety factor to these values reduces them to values similar to those reported by Naik[30].

Table 3: Rule-of-thumb ratios according to Janssen[3] and resulting stresses for mechanical properties of bamboo (assuming an average density of 783 kg/m³)

	Modulus of rupture	Compression	Shear
Ratio[3]	0.14	0.094	0.021
Stress (MPa)	110	74	17

Thus, it is recommended that the ratios be used for preliminary designs only and that the species to be used in construction be tested to determine more precise and reliable values prior to final design and construction. Furthermore, we recommend the use of the safety factors suggested in the international design standard for bamboo, namely ISO 22156.[27]

Density

Bambusa balcooa has a density generally between 720 kg/m³ and 850 kg/m³ (Table 2), somewhat higher overall than South African pine[31], which varies from 450 kg/m³ to 800 kg/m³, and is considerably lighter than steel at 7800 kg/m³.

The lightness of this material is advantageous in conventional construction, as the low mass will reduce the load on the foundations, which can consequently be smaller and less costly. In a seismic situation, the light weight will result in lower downward and lateral loads, resulting in a smaller seismic load on the structure. Furthermore, the bamboo culm's flexibility and ductility allow the structure to absorb vibrational forces with minimal damage.

However, in high wind situations, more weight in the building is preferable to counteract the wind forces. In areas where moderate to high wind forces occur, heavier foundations or sturdier structures would improve the structure's stability and assist in counteracting the wind forces. In addition, the superstructure (and foundations) should be designed and constructed to function as a unit, thus increasing the resisting mass of the building. According to the Beaufort wind scale, an empirical measure of observed wind speed[32], South Africa is considered a moderate wind range area with the highest wind speeds occurring in the Northern Cape. Thus, although some modification to increase the weight of the foundations or buildings would be necessary, this would not be considered a limiting factor.

Typically, industrial warehouses and long-span roofs are designed and constructed from structural steelwork because concrete beams become too bulky, whereas steel can still be slender for the same properties. Conventional gang nail timber trusses can span to approximately 9 m; thereafter, laminated timber beams become preferable, which would increase the cost of the project. Bamboo is lighter than steel, and trusses can be formed to span these lengths and longer, such as those designed by Asali Bali Engineers in Indonesia and surrounding areas (Figure 7), which span up to 20 m.[33]

Image: ©Olivier Betting[33]; reproduced with permission

Figure 7: Bamboo warehouse by Asali Bali Engineers.

Durability

According to the available literature, untreated bamboo structures typically have a lifespan of 10–15 years[3], being susceptible to attack by fungi and insects. In addition, bamboo deteriorates when exposed to moisture. However, with preservation, this lifespan can be extended to approximately 25 to 30 years[3,5], depending on the exposure conditions.

Typically, buildings are designed for a 50-year lifespan; thus, bamboo's shorter lifespan could limit this material's usage or restrict its usage to temporary or semi-permanent structures. In addition, the cost of the preservation of the bamboo culms will increase the cost of the structures built in terms of total lifetime cost.

Further research is required to establish whether the lifespan of bamboo culms can be extended to 50 or more years with suitable preservation, focusing on the bamboo species found in South Africa.

Failure modes

Columns typically fail by crushing or by buckling, such as when the load applied to the longitudinal axis of the column exceeds the compressive strength of the material of the column (crushing) or when the load leads to deformation of the column, leading to instability (buckling). When bamboo columns fail due to a compressive load, the lateral bond fails between the longitudinal fibres, and the circular form of the cross-section no longer provides resistance. In addition, bamboo tends to fail in shear by splitting and cracking, such as when loads are applied at bolted connections (Figure 8), due to the hollow structure, lack of cross fibres in the internodes and low circumferential tensile strength.

Image: ©Kent Harries[41]; reproduced with permission

Figure 8: Splitting failure due to bolted connections.

In order to overcome this, bamboo structures should be designed to avoid internodal point loads, transferring all loads at the nodes of the culm. Alternatively, specialised steel connections may be designed to transfer the loads, strengthening the bamboo culm's nodal points, such as those developed by Christoph Tönges.[34]

This failure mode of bamboo presents a modicum of safety, as a failure in this way does not indicate complete failure of the entire culm but instead indicates imminent failure. In this way, a margin of safety is available to escape from the structure prior to collapse.

Analysis, design and modelling aspects

As mentioned, the variations in physical geometry present problems with the design. Most structural engineering formulae and design software assume that the members being designed are constant along their length, with isotropic material properties. Not only do the culms vary along their length, but due to the composition of the fibres, they are also anisotropic, having different material and engineering properties in the longitudinal, radial and tangential directions. Several guidelines are available in the literature to overcome these issues, such as assuming average properties along the culm's length and using properties from test samples when designing detailed connections. Kaminski et al.[7] suggest that a series of measurements should be taken and equations used to calculate the various properties based on these measurements. In a similar vein, Silva et al.[35] proposed using graded elements incorporating the measured material properties at integration points for use in a finite element method analysis, specifically when designing for local stresses near supports, pin connections or holes.

In contrast, Sharma[36] modelled a bamboo portal frame in two dimensions, using beam elements with appropriate geometric and material properties to represent the individual culms. Thus, the variations in the culm properties could be modelled with varying beam elements. Sharma compared the theoretical results from the calculations with results from an experimental model and concluded that the theoretical model had captured the fundamental behaviour of the proposed portal frame.

Irregular geometry could also result in irregular structures. The irregularities can either be minimised by careful selection of the culms to be used or incorporated as part of the aesthetics of the structures. All these aspects, of course, have implications for the overall and detailed design of the structures.

Guidelines and codes for bamboo construction in South Africa

There are currently no South African design codes for the design or construction of bamboo structures. As mentioned earlier, INBAR has published several guidelines and material values that can be used for the preliminary sizing and design of such structures, such as *Designing and Building with Bamboo – Technical Report 20*[3] and *Design of Bamboo Scaffolds – Technical Report 23*[37]. The technical series by Kaminski et al.[4-7], also mentioned earlier, presents the design process using a limit state approach.

Codes from other countries or sources may also be used, such as the National Building Code of India[26] or the International Code for Bamboo, ISO 22156 and 22157[27-29]. These were discussed previously, as were the recommendations of authorities such as Janssen[3].

As bamboo construction is not yet an accepted form of building construction in South Africa, as defined by the NHBRC (National Home Builders Registration Council), additional tests and calculations would be required to obtain building permits, such as load-bearing capacity and behaviour in fire. Although reference can be made to the ISO standards in a rational design, these calculations would still be required.

Many Eastern countries, such as India, China and Japan, have a history of bamboo construction and have adapted their construction and design methods to suit the vagaries of their local bamboo species. These adaptations can be transferred in principle to bamboo construction in other countries where bamboo construction is uncommon, such as South Africa.

Conclusions

Although there are possibilities to use other bamboo species for construction, there are two species in South Africa currently considered suitable, namely *B. balcooa*, a naturalised species, and *Beema bamboo*, a clone of *B. balcooa.* Unfortunately, some of the attempts to grow these bamboo species have failed, and the remaining growers and nurseries do not have quantitative production figures. However, local reports indicate that South Africa has the potential to expand its bamboo growth industry to meet potential demand.

The engineering and material properties of *B. balcooa* as found in South Africa have not yet been established. Testing would be required to determine these design parameters before bamboo design and construction could become commonplace in South Africa.

As bamboo design is not included in any South African design code, it would be necessary to use codes and guidelines from other countries, such as ISO 22156: Bamboo – Structural Design.

The limitations for bamboo design and construction are not unique to South Africa but are common to other countries involved in bamboo construction. Their experience in overcoming these limitations can be transferred to the use of bamboo in South Africa, making bamboo construction a viable building technology in South Africa.

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Competing interests

We have no competing interests to declare.

Authors' contributions

S.R.: Conceptualisation; research; writing. M.A.: Conceptualisation; student supervision; review of writing and revisions.

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