USE OF BAMBOO CONSTRUCTION

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BAMBOO

Bamboos are evergreen perennial floweringplants. In bamboo, as in other grasses, the internodal regions of the stem are usually hollow and the vascular bundles in the cross-section are scattered throughout the stem instead of in a cylindrical arrangement.

Bamboos include some of the fastest-growing plants in the world, due to a unique rhizome-dependent system. Certain species of bamboo can grow 910 mm (36 in) within a 24-hour period, at a rate of almost 40 mm (1 ½ in) an hour (a growth around 1 mm every 90 seconds, or 1 inch every 40 minutes).[6] Giant bamboos are the largest members of the grass family. This rapid growth and tolerance for marginal land, make bamboo a good candidate for afforestation, carbon sequestration and climate change mitigation.

Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product. Bamboo, like wood, is a natural composite material with a high strength-to-weight ratio useful for structures.[7] Bamboo's strength-to-weight ratio is similar to timber, and its strength is generally similar to a strong softwood or hardwood timber.

Unlike all trees, individual bamboo culms emerge from the ground at their full diameter and grow to their full height in a single growing season of three to four months. During this time, each new shoot grows vertically into a culm with no branching out until the majority of the mature height is reached. Then, the branches extend from the nodes and leafing out occurs. In the next year, the pulpy wall of each culm slowly hardens. During the third year, the culm hardens further. The shoot is now a fully mature culm. Over the next 2–5 years (depending on species), fungus begins to form on the outside of the culm, which eventually penetrates and overcomes the culm. Around 5–8 years later (species- and climate-dependent), the fungal growths cause the culm to collapse and decay. This brief life means culms are ready for harvest and suitable for use in construction within about three to seven years.

Bamboo, like true wood, is a natural building material with a high strength-to-weight ratio useful for structures.

In its natural form, bamboo as a construction material is traditionally associated with the cultures of South Asia, East Asia, and the South Pacific, to some extent in Central and South America, and by extension in the aesthetic of Tiki culture. In China and India, bamboo was used to hold up simple suspension bridges, either by making cables of split bamboo or twisting whole culms of sufficiently pliable bamboo together. One such bridge in the area of Qian-Xian is referenced in writings dating back to 960 AD and may have stood since as far back as the third century BC, due largely to continuous maintenance.

Bamboo has also long been used as scaffolding; the practice has been banned in China for buildings over six stories, but is still in continuous use for skyscrapers in Hong Kong. In the Philippines, the nipa hut is a fairly typical example of the most basic sort of housing where bamboo is used; the walls are split and woven bamboo, and bamboo slats and poles may be used as its support. In Japanese architecture, bamboo is used primarily as a supplemental or decorative element in buildings such as fencing, fountains, grates, and gutters, largely due to the ready abundance of quality timber.

BAMBOO CONSTRUCTION

Bamboo can be utilized as a building material for scaffolding, bridges, houses and buildings. Bamboo, like wood, is a natural composite material with a high strength-to-weight ratio useful for structures. Bamboo's strength-to-weight ratio is similar to timber, and its strength is generally similar to a strong softwood or hardwood timber.

House made entirely of bamboo

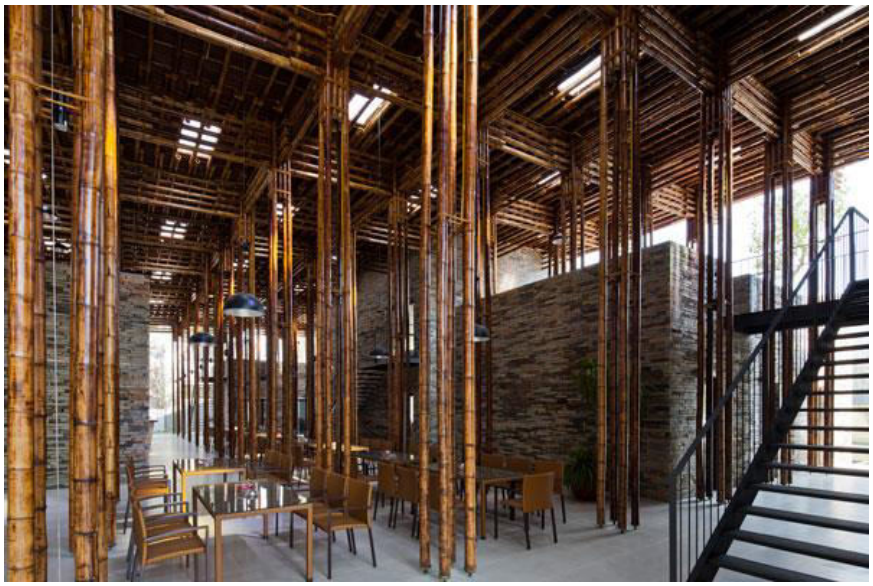
Over the past few decades, there has been a growing interest in using bamboo round poles for construction, primarily because of its sustainability. Famous bamboo architects and builders include Simón Velez, Marcelo Villegas, Oscar Hidalgo-López, JörgStamm, Vo TrongNghia, Elora Hardy and John Hardy. To date, the most high profile bamboo construction projects have tended to be in Vietnam, Bali (Indonesia), China and Colombia. The greatest advancements in structural use of bamboo have been in Colombia, where Universities have been conducting significant research into element and joint design and large high profile buildings and bridges have been constructed.[8] In Brazil, bamboo have been studied for more than 40 years at the Pontifical Catholic University of Rio de Janeiro PUC-Rio for structural applications. Some important results are: the bamboo bicycles, the bamboo space structure with rigid steel joints, the deployable bamboo structure pavilions [10] and the active bending bamboo amphitheater structure with flexible joints

The Properties of bamboo

Bamboo, a highly versatile resource and widely available, is being used as an engineering material for the construction of houses and other buildings. There are some inherent properties of bamboo,that makes it a preferred material for longevity and sustainability, which are discussed below.

Tensile strength

Bamboo is able to resist more tension than compression. The fibres of bamboo run axially. In the outer zone are highly elastic vascular bundles that have a high tensile strength. The tensile strength of these fibres is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicated outer skin, axial parallel elastic fibers with a tensile strength upto 400 N/mm^2 can be found. As a comparison, extremely strong wood fibers can resist a tension upto 50 N /mm^2.



Compressive strength

Compared to the bigger tubes, slimmer ones have got, in relation to their cross-section, a higher compressive strength value. The slimmer tubes possess better material properties due to the fact that bigger tubes have got a minor part of the outer skin, which is very resistant to tension. The portion of lignin inside the culms affects compressive strength, whereas the high portion of cellulose influences the

buckling and the tensile strength as it represents the building substance of the bamboo fibers.

Elastic modulus

The accumulation of highly strong fibers in the outer parts of the tube wall also work positively in connection with the elastic modulus like it does for the tension, shear and bending strength. The higher the elastic modulus, the higher is the quality of the bamboo. Enormous elasticity makes it a very useful building material in areas with very high risks of earthquakes.

Anisotropic properties

Bamboo is an anisotropic material. Properties in the longitudinal direction are completely different from those in the transversal direction. There are cellulose fibers in the longitudinal direction, which is strong and stiff and in the transverse direction there is lignin, which is soft and brittle.

Shrinkage

Bamboo shrinks more than wood when it loses water. The canes can tear apart at the nodes. Bamboo shrinks in a cross section of 10-16 % and a wall thickness of 15-17 %. Therefore it is necessary to take necessary measures to prevent water loss when used as a building material.

Fire resistance

The fire resistance is very good because of the high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside.

The working of bamboo

The work of bamboo is used as per the desired need and length. The different working of bamboo involves

Splitting

The cane is split in halves and quarters and then driven apart by a wedge. It can also be split with a knife frame into four or eight segments. By means of splitting you get halved canes, strips and battens. To get planks, all the nodes are smashed and the wall of the pole is split over its entire length and forced open until the wall of the pole lies flat. Up to the age of 18 months, the canes can be peeled. The strips can be used as ties or be woven to make strings and ropes.

Shaping

Bamboo available in nature is usually circular in cross section. But if bamboo is made to grow in a box of square shape it attains the shape of that box, so that it can be better used for making connections.

Bending

Freshly cut, bamboo can be bent by heating and will keep this shape after drying. When heated above 150° C, bamboo starts changing its shape and remains as such after it goes cold.

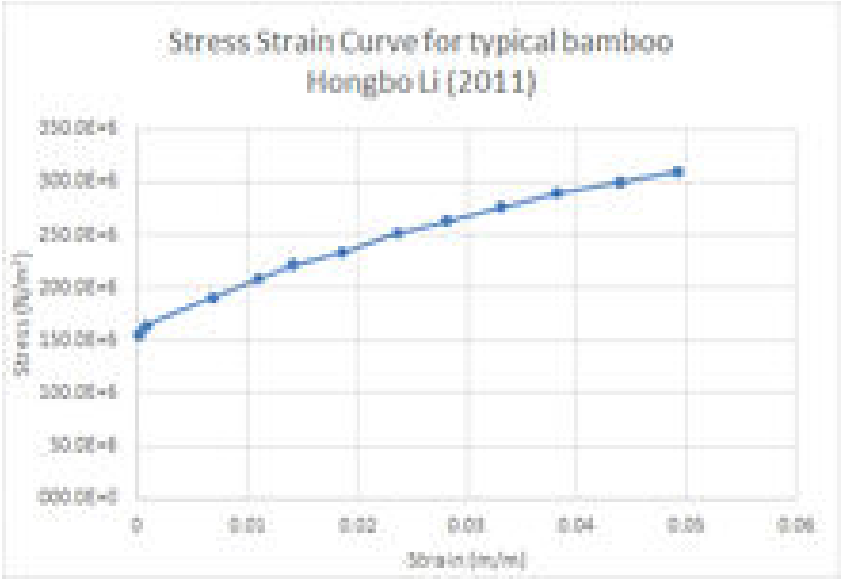
Structural design codes

The first structural design codes for bamboo in-the-round were published by ISO in 2004 (ISO 22156 Bamboo - structural design, ISO 22157-1 Bamboo – Determination of Physical and Mechanical properties part 1 and ISO 22157-2 Bamboo – Determination of Physical and Mechanical properties part 2: Laboratory manual. Colombia was the first country to publish a country-specific code in the structural use of bamboo (NSR-10 G12). Since then, Ecuador, Peru, India and Bangladesh have all published codes, however the Colombian code is still widely considered to be the most reliable and comprehensive.

Curved structural shapes

Heat and pressure is sometimes traditionally used to form curved shapes in bamboo.

Structural Behaviour



Stress Strain Curve for Bamboo

A typical bamboo shows a nonlinear stress-strain behaviour。It can restrain strain of up to 0.05 until it breaks at which the stress level can be about 300 MPa.

Durability

Bamboo is more susceptible to decay than timber, due to a lack of natural toxins [15] and its typically thin walls, which means that a small amount of decay can mean a significant percentage change in capacity. There are three causes of decay:

beetle attack, termite attack and fungal attack (rot). Untreated bamboo can last 2–6 years internally, and less than a year if exposed to water.

In order to protect bamboo from decay, two design principles are required:
The bamboo must be kept dry throughout its life to protect it against rot (fungi). This fundamental architectural principle is called "durability by design", and involves keeping the bamboo dry through good design practices such as elevating the structure above the ground, using damp proof membranes, having good drip details, having good roof overhangs, using waterproof coatings for the walls, etc.

The bamboo must be treated to protect it against insects (namely beetles and termites). The most common and appropriate chemical to treat bamboo is boron, normally either a mixture of borax and boric acid, but it also comes in one compound (di-sodium tetraboratedecahydrate).

Both principles must be applied to a design in order to protect bamboo. Boron by itself is inadequate to protect against rot, and it will wash out if exposed to water.[16]
Modern fixed preservatives may be used as alternatives to boron such as copper azole, however little bamboo has been reliably tested using these methods to date. In addition, they tend to be more hazardous for the treatment workers and the end user, and therefore are less appropriate for developing countries, which is where bamboo is currently mostly used.[16]
Natural forms of bamboo treatment such as soaking in water and exposing to smoke may provide some limited protection against beetles, however, there is little evidence to show they are effective against termites and rot, and are therefore not typically used in modern construction.[18]

Applications of Bamboo for construction and architecture

After global warming and sustainability issues emerged, bamboo as building materials is widely discussed and reviewed. Some architects and builders nowadays tend to choose bamboo for building material. High-quality woods for construction are rarely found nowadays because of deforestation. Wood also takes a long time to regrow and is ready to use as construction materials. Meanwhile bamboo can be harvested in a short time, which is between 3-5 years. When planting, bamboo also releases oxygen into the air, the ability that cannot be performed by industrial materials like steel, plastic and concrete. For these reasons, bamboo has been widely known as sustainable building materials and is being used in architectural and construction works. Each of them is explained below.

Bamboo Courtyard Teahouse by HWCD Associates

bamboo installation, dimensions variable, singapore

Children’s activity and learning center, Thailand

Luum Temple, MEXICO

Bamboo used in Architecture

In bamboo architecture, bamboo, as the main architectural structure, plays the role of load holding of buildings. Bamboo has strong adaptability in thickness and strength and can make different combination adjustments accordingly based on the architectural structure to satisfy the requirement of different structural performance. On the other hand, the technical requirements of bamboo buildings are relatively low and can easily be integrated into local architectural structures, for example, the integration of bamboo with soil, concrete, and glue, etc, can help increase the structural strength. The stiffness, strength and stability of nodes mainly are mainly

based on the joint strength between structure components of the building. Therefore, the increasing improvement of connection structure has brought more contributions to the diversification of bamboo architecture.

Bamboo used as Building "Skin"

The outwalls of buildings can be called "Skin", which can reflect the culture of the building. The diversity in bamboo use and its integration with other materials provides more opportunities to the diversification of building "skin" and the improvement of architectural aesthetics. Typically, the use of bamboo as building skins can be divided into three types:

(1) Single skin: A "bamboo skin" formed by only one material through various combinations, which is a relatively low level application of one kind of bamboo material in building skins. It is of simple production technology with low cost and good ventilation and sunlight prevention. Besides, it is helpful for keeping the architectural features with local architectures, however, it has shortcomings such as poor lighting conditions and privacy. Therefore, it is usually used in exterior space and the enclosure of less important space.

(2) Multilayer skin: Juxtaposed and composed by two or more materials, which is a typical design method of using complementation of material properties, and can effectively overcome defects of single bamboo material. The juxtaposition of bamboo and glass is a very common 1909 combination form. The bamboo can filter outside inference (such as sunlight, the line of sight), and glass can block the sound and heat that bamboo cannot filter. The exchange between indoor and outdoor environments occurs from the open and close of the bamboo curtain, creating a breathable skin.

(3) Composite skin: Created by blending two or more materials, which breakthroughs their inherent properties and creates a third type of skin. In general, new skin incorporates the advantages of composite materials, for example, the composition of bamboo and rammed earth walls can both effectively reduce the weight of rammed earth walls and enhance the force bearing capability along the radial direction of bamboo.

Bamboo used as Building Decoration

Building decoration can be divided into architectural interior and exterior decoration. Building interior decoration should fully considerate the natural characteristics of bamboo materials. The surface of bamboo materials is smooth, lightweight and flexible, with natural and gentle color, clear and beautiful texture. Bamboo decoration

should make full use of the sense of reality, color, surface gloss and texture to reflect the nature of bamboo materials. The main decoration colors of bamboo materials include bamboo green, tabasheer and carbonization. In addition, bamboo can easily be bent, making it an ideal material for manufacturing all kinds of beautiful furniture. Besides building skins, external decoration of buildings also includes virescence surrounding the building. The greening effect of bamboo on buildings can present in many forms, which can be classified into three main categories: clump, row, and tract. Bamboo grove in clump shape is concise and clear, pure and fresh, which is suitable for ornament and decoration to improve the taste of a building; bamboo grove in row shape is usually used in boundary space. Besides the role of decoration, it also has the function of blocking and shielding; to foil the environmental atmosphere, bamboo grove in tracts can usually be seen in an open area,

Bamboo used as laminated sheets and planks

Bamboo can be cut and laminated into sheets and planks. This process involves cutting stalks into thin strips, planing them flat, and drying the strips; they are then glued, pressed and finished. Long used in China and Japan, entrepreneurs started developing and selling laminated bamboo flooring in the West during the mid-1990s; products made from bamboo laminate, including flooring, cabinetry, furniture and even decorations, are currently surging in popularity, transitioning from the boutique market to mainstream providers such as Home Depot. The quality of bamboo laminate varies among manufacturers and varies according to the maturity of the plant from which it was harvested.

Bamboo used in doors and windows

Bamboo used in Architecture

Bamboo used in roof

Bamboo used in wall

Bamboo used in scaffolding

Bamboo used as Building “Skin”

Bamboo used as Building Decoration

Bamboo used as laminated sheets and planks

Bamboo used in floor

Bamboo used in foundation

In spite of their short life considerable use of bamboo is made as foundation or supporting posts in case of houses built on raised platforms. The various types of foundations constructed with bamboo are, Bamboo which is in direct contact with ground surface, Bamboo fixed to rock or preformed concrete footings, Composite bamboo or concrete columns and Bamboo piles.

Bamboo used in floor

Bamboo has been used as an alternative for flooring because of its physical similarities to true hardwoods. Bamboo floor manufacturers and sellers promote its strength, durability, its eco-friendliness and its natural resistance to insects and moisture. The hardness of traditional bamboo flooring ranges from 1180 (carbonized horizontal) to around 1380 (natural), while newer manufacturing techniques including strand woven bamboo flooring range from 3000 to over 5000 using the Janka hardness test. The various types used are, Small bamboo culms, Split bamboo and Flattened bamboo.

Bamboo used in wall

The most extensive use of bamboo in construction is for the walls and partitions. The major elements, the posts and beams, generally constitute part or structural framework. They are to carry the self-weight of building and loads imposed by the occupants and the weather. An infill between framing members is required to complete the wall.

Bamboo used in roof

The roof offers protection against extremes of weather including rain, sun and wind, and to provide shelter, clear and usable space beneath the canopy. The bamboo structure of a roof can comprise of purlins, rafters and trusses. The different forms include, a bamboo purlin and beams, supported on perimeter postsCorrugated sheets made out of bamboo, a layer of bitumen is sandwiched between two mats of bamboo and Plastered bamboo.

Bamboo used in scaffolding

Bamboo material is environmentally-friendly and low-cost. It has been widely used in the construction of new buildings, renovation, repair works, slope maintenance, and neon signage works. Most of the construction operations require the use of scaffolding and material is an important factor, which affects the competitiveness as well as its overall investment. Because of the favorable relationship between load-bearing capacity and weight, bamboo can be used for the construction of safe scaffoldings even for very tall buildings. Only lashed joints are used. The cane extension is carried out by lashing the cane ends together with several ties. The ties are arranged in such a way that forces acting vertically downwards wedges the nodes in the lashing.

Bamboo used in doors and windows

Bamboo replaces timber frames appropriate to function. mat shutters fixed to bamboo frame bamboo boards fixed to the frame which wall can be used as a door. Small frame to the top of the wall can serve as windows.

Modern use of laminated bamboo for construction

Bamboo can be cut and laminated into sheets and planks. This process involves cutting stalks into thin strips, planing them flat, and drying the strips; they are then glued, pressed and finished. Long used in China and Japan, entrepreneurs started developing and selling laminated bamboo flooring in the West during the mid-1990s; products made from bamboo laminate, including flooring, cabinetry, furniture and even decorations, are currently surging in popularity, transitioning from the boutique market to mainstream providers such as Home Depot. The bamboo goods industry (which also includes small goods, fabric, etc.) is expected to be worth $25 billion by 2012.[19] The quality of bamboo laminate varies among manufacturers and varies according to the maturity of the plant from which it was harvested (six years being considered the optimum).

Bamboo as an alternative to steel

Bamboo has been used in the construction field for a long time, even before its tensile strength was known. People used to build houses, furniture, fences, etc. with bamboo.

Our modern-day researchers and engineers are looking forward to replacing steel with bamboo due to its tensile properties.

The use of steel in concrete is costly, and the production of steel has a lot of drawbacks like high costs, atmospheric pollution, and environmental degradation. The bamboo, on the other hand, can be produced at very low costs and has various environmental benefits.

However, we cannot use bamboo to replace steel directly as the tensile strength alone is not enough, even though bamboo is found to be stronger and stiffer than other construction materials.

The plant, however, is prone to attack by insects and can degrade in the presence of water. Long-term durability and shrinkage are also factors to consider.

Extensive research is already underway to eliminate all these shortcomings and boost the existing properties of bamboo. These studies focus on the mechanical and physical properties of the plant and on finding the species that are most useful.

The Swiss Federal Institute of Technology Zurich is developing a bamboo composite called the BambooTECH, which they believe can replace steel with its strength, high versatility, and durability.

MIT scientists and architects have found the bamboo wood to be denser and stronger than softwoods like spruce, fir, and pine. They are trying to exploit the properties of bamboo to develop it into a better construction material, which can then be used to build more resilient buildings.

Engineering using bamboo: What the future has in store for us!

The use of bamboo, also known as the 'poor man's timber,' in the field of engineering is also numerous. Environmental organizations are promoting bamboo due to its variety of excellent properties and oxygen emission capacity.

Its high tensile strength, ability to withstand compression, and bending property makes it a very promising material in the field of construction. Designers see bamboo as an alternative to lumber.

Bamboo wooden panels offer a natural aesthetic look and finish. Flooring, cabinets, and household items made from bamboo are more durable and less costly.

When researchers weaved bamboo with epoxy, they ended up with a composite that is stronger than carbon fiber. This gives us hope that one day, bamboo can be used to create an alternative to carbon fiber.

The greatest of all advantages is that it is **100 times** cheaper compared to carbon fiber.

The low cost, wide availability and strength of the bamboo have made it possible to use this plant in the construction of shelters and large disaster relief projects.

Some of the examples are:

Flood resistant houses in Vietnam

Housing for victims of the earthquake in Nepal

Temporary accommodation in Thailand for Burmese refugees

Apart from its potential to replace steel, researchers believe that bamboo can also be used to replace plastic pipes used in construction.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In tensile load application, results shown by bamboo are exciting because the ratio of tensile strength to the specific weight of bamboo is six times greater than steel.

Conclusion

India is still catching up with the world in adopting the newly developed bamboo building construction technologies for mainstream buildings. Several research institutes are working on bamboo building systems, but the lab to land transfer is very slow. Alternative technologies need to be seriously viewed in light of global warming and rising inflation. The properties as a top-grade building material and increased availability of bamboo in our country make it possible to use bamboo in the field of construction extensively. Its high valued utilization not only promotes economic development but also saves forest resources to protect our ecological environment as a wood substitute. As an economic building material, bamboo's rate of productivity and cycle of annual harvest outstrips any other naturally growing resource.

AMAZING THINGS YOU CAN DO WITH BAMBOO

The low cost of bamboo reduces the overall cost of construction and makes it affordable to everyone.

Another significant merit of growing bamboo is that no part of the plant gets wasted. Taking these facts into consideration, it is a good idea to promote the growth and use of bamboo to ensure lower costs of living and a better environment for our future generations.

Common myths and misconceptions in the use of bamboo for construction

There are a number of common myths and misconceptions surrounding the use of bamboo for construction.

Myth 1: "Bamboo is stronger than steel."

This is a very common statement, and is derived from two sources:

Since bamboo has a strength-to-weight ratio similar to mild steel, some people conflate this with actual strength.

A few laboratory tests have shown some parts of some species of some culms to have ultimate strengths in tension approaching mild steel (250N/mm^2).

In reality though, even if some fibres of some species show relatively high strengths, following international practice, the design strength that can be safely used is closer to 5–10% of this value, to account for the variability of the strengths.

Myth 2: "Bamboo only needs to be treated to protect it from decay."

As described above, bamboo also needs to be kept dry in order to protect it from rot, and many existing bamboo structures are showing signs of rot because they did not follow the principles of durability by design.

Myth 3: "Bamboo performs well in earthquakes because it 'sways' and 'absorbs energy'."

Bamboo is a brittle material and therefore by itself unable to absorb energy in earthquakes. There is also no advantage of its low stiffness in terms of the performance of bamboo buildings in earthquakes Instead, bamboo structures are primarily good in earthquakes because:

They tend to be light.

Joints in bamboo buildings are able to absorb some energy.

Myth 4: "Bolted connections cannot be used in bamboo structures."

Plain bolted connections can show brittle behavior due to longitudinal splitting of bamboo culms. Providing confinement to bamboo culms at the connection zones increases resistance to this failure mode and brings significant improvement to strength and ductility.

More importantly, bolted connections display predictable yielding. This is vital for performing a rational engineered design.The bolts are also widely available, easy-to-use and versatile.

Myth 5: "Bamboo can be used as a replacement for steel in reinforcement."

This misconception stems from the original idea that bamboo is stronger than steel, and hence could simply replace steel in reinforced concrete.

In reality, bamboo does not function well as a replacement for steel in concrete for the following reasons:

Bamboo has $\approx {}^{1}/_{30\text{th}}$ of the capacity of high yield steel which is most commonly now used in construction, so one would need 30× extra material. There is no space for this in reinforced concrete.

To ensure a proper connection between the bamboo and the concrete, one needs to use expensive chemicals to form the bond, which are bad for the environment.

Concrete is unable to protect the bamboo from fungal and termite attack.

Bamboo is a brittle material and therefore cannot itself absorb energy in an earthquake, unlike steel.

Once all of the above are considered, concrete reinforced with bamboo has a higher environmental impact than concrete reinforced with steel.

BIBLIOGRAPHY

- https://en.wikipedia.org/wiki/Bamboo
- https://en.m.wikipedia.org/wiki/Bamboo_construction#Modern_use_of_bamboo_round_poles_for_construction
- https://www.constrofacilitator.com/advantages-and-application-of-bamboo-in-modern-design/