



USING BAMBOO IN TRADITIONAL HOUSING AND MODERN ARCHITECTURE

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Abstract: Bamboo has been very familiar with many generations of Vietnamese people. Besides its wide application as a useful tool in agricultural work, household appliances, and as defensive weapons, bamboo has also been used as a material in traditional housing in Vietnam. Nowadays, the exploitation and the over use of environmentally unfriendly materials in building construction have been affecting the natural environment, causing climate change. Therefore, within the scope of this article, the research of the usability of bamboo in traditional housing as well as in modern buildings in order to preserve and develop bamboo as a low-cost material, an easy planted, tree exploitation and construction material in buildings should be discussed. Several conventional research methods such as data collection, analysis, statistics, comparison, studies of historical experience and forecasting for a reconsideration of the values and usability of bamboo in traditional housing and modern architecture are introduced in the paper in order to accomplish the objectives to be set.

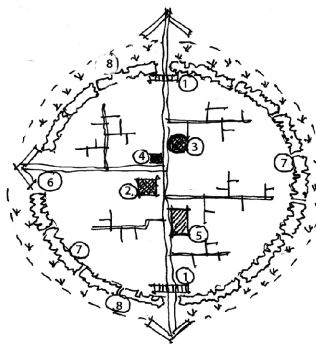
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1. The values of bamboo

Bamboo has been important to Vietnamese farmers for centuries. Bamboo is always highly appreciated and widely used as tools for work, household appliances, decorative items, a building material and defensive weapons. Bamboo trees are grown along river dykes to reduce erosion, landslide and inundation. Bamboo trees are put around villages to protect villagers (Fig. 1). Bamboo trees can also be seen in the gardens of traditional country houses: they are planted into thick bamboo fences to mark the borderlines of the farmers' plots of land; or planned on the west side of a precinct to shelter the main house from solar radiation. Additionally, bamboo is grown for building purpose.



- Annotations:
1. Village entrance gate
 2. Village communal house
 3. Village pagoda
 4. Fane, shrine
 5. Village market
 6. Gate to paddy field
 7. Surrounding bamboo fence
 8. Paddy Field

Figure 1. A village structure of the Vietnamese with surrounding bamboo fence

At first, traditional houses of the Vietnamese were mostly constructed with bamboo, from supporting frames (truss systems) to wall and roof structures. People decided to choose bamboo for different structures and components, such as columns, roof trusses, cross beams, rafters, laths, wattles, etc., depending on the size and the quality of bamboo. These components made of bamboo can be bound together by means of strings or fastening dowels. In traditional architecture, bamboo is rather limited in terms of spanning: a bamboo truss can span from 3.5 to 4.5 meters and the distance between two trusses may be 2.7÷3 meters. Nowadays, bamboo is widely applied in modern architecture, for instance communal houses, schools, kindergartens in the areas frequently affected by flood, or buildings erected on soft grounds, entertainment parks, resorts, etc. In the modern architecture, apart from strings and fastening dowels as conventionally practiced, it is possible to use steel for binding component, for example iron wires, iron dowels, iron hoops

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and iron bolts, etc. Traditionally, only two bamboo canes could be put together. But today, many bamboo canes can be tied up into a bunch with steel bindings and then developed into a more complex structure that will be able to span up to 15 meters. In modern architecture, bamboo as a material has also been employed for architectural shapes with light weight, curves, flexibility and rhythm as great advantages. Thus, it can be seen that the use of bamboo materials in architecture and construction of housing today still remains as valuable as it used to be in the past and promises to be potential in the future.

Bamboo trees can be grown and harvested in view of sustainability. In the wild nature, bamboo trees grow in forests in large quantity across the midland and mountainous areas and are also planted in the countryside of Vietnam. In the past, bamboo was harvested reasonably in a small amount. Recently, the exploitation on a large scale without an alternative development policy has resulted in an increasing shortage of bamboo. In this regard, the government must take its full responsibility to issue a policy in terms of bamboo growing into forests and manage industrial exploitation in a sustainable and effective way.

Bamboo has cluster roots, so it is possible for bamboo to sustain soil moisture and prevent soil erosion. Bamboo can be planted to green bare hills in the midland, and especially if arranged along streams or rivers, bamboo can protect and mitigate the damage of the flow of landslides.

Bamboo has a high potential in wind- and storm-resistance, and its load-bearing capacity is twice better than timber. In comparison to timber, the compression strength of bamboo is 10% higher, and its tensile strength per weight unit is three to four times greater than that of wood [1].

Bamboo is an eco-friendly building material, and it is possible to be recycled. Once being burned to ashes, it turns into a natural inorganic fertilizer that will provide more nutrients for the fertility of the soil. Due to the origin from cellulose, bamboo ash can replace phosphate and potassium in agriculture.



2. Using bamboo in traditional housing

Materials used to build the tradition houses are mainly local and friendly such as earth, stone, wood and especially bamboo. With a simple structure and the ability to be constructed easily and to use simple labor skills, bamboo houses are able to resist storms and other natural catastrophes. In addition, bamboo and wood are naturally produced with sustainable supply source because they are easy to be planted and exploited. With a short life-cycle, bamboo trees can grow anywhere in almost all soil conditions. For material preparation of the traditional house, bamboo was carefully chosen and specially treated. Bamboo trees should be straight, long and large enough. They were put in pond water for about six months. As a result, they became termite- and weather-resistant (nowadays, bamboo trees are chemically treated instead, but chemicals are usually pollutants). After that treatment, bamboo trees were used for different purposes and different components of a house, depending on the size, the length and the straightness. Straight and large bamboo trees were suitable for columns, roof trusses and/or cross beams, while smaller bamboos were used for purlins. Small bamboos might be split for rafters and laths, or interwoven into bamboo wattles for sun shading. In that case, straw and rice stubble were properly cut (5 to 10 centimeters) and mixed with mud from fish ponds and clay. This soft mixture was plastered on both sides of a curtain wall. Those straw strings prevented mud from coming off from the bamboo wattle when it dried (see Fig. 2). Bamboo wattles could be applied to doors and windows that helped to protect the house so well from splashing rain and burning sunlight. Split (or non-split) bamboos were used to make girders. Rafters and laths required split bamboo rods. Similarly, bamboo laths were interwoven with straw or rice stubble or several kinds of plants, and manually made into bunches as a perfect thatching material (see Fig. 3). Bamboo wattles were frequently installed in the veranda of a house as shields against solar radiation as well as heavy rain (see Fig. 4). Both bamboo strings and bamboo dowels were used to tie up or connect several construction components together. In truly traditional houses, there were absolutely no metal bindings. Hence, only by using bamboo was it possible to build and finish an entire house that ensured comfort for residents [2,3].

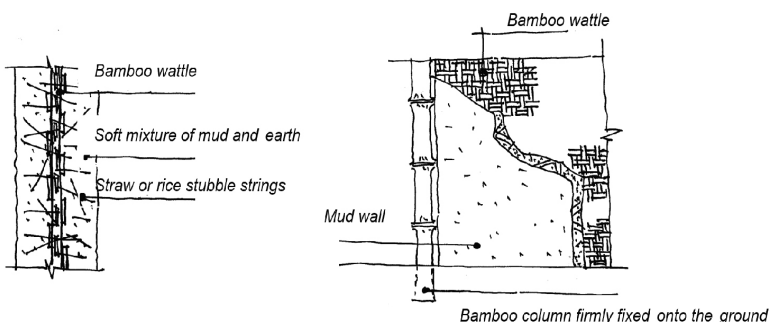


Figure 2. Mud wall structure

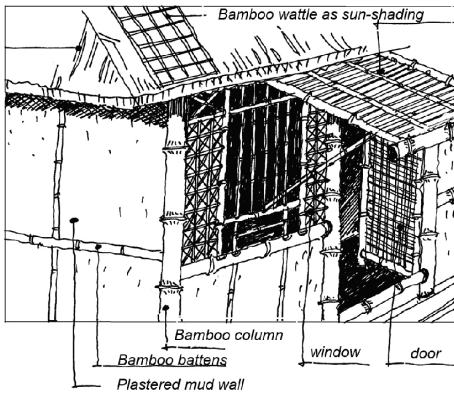


Figure 3. Bamboo components in a traditional house



Figure 4. Bamboo wattle as a sun-shading element in The Former President Ho Chi Minh's country house

3. Types of bamboo truss in traditional housing

Based on a built form, a binding method and load-bearing capacity, bamboo trusses can be divided into several categories as follows:

- Three-column truss;
- Transversal-beam truss with two columns and a post in the middle to the ridge;
- Transversal-beam truss with a T-shaped post in the middle;
- Simple transversal-beam truss (without a post in the middle).

Three-column truss: This system consists of three straight bamboo trunks vertically erected as three columns. The middle column is a main one, higher than the other two, in order to support the ridge. The other two columns just reached the top of the front wall and back wall. The truss is often a double structure, made of two bamboo chords exactly the same in length and in size. In addition, there is a transversal beam that joins the chords and the columns together. This three-column system is firmly fixed onto the ground. Horizontal bamboo braces are used to connect the members of the truss system with one another, and called cross beams or upper cross beams. In some houses, additional beams are used (and put straight on the ground floor) to connect the bases of the peripheral columns together, in order to strengthen the whole structure (just like in case of multiple door leaves in Vietnamese traditional wooden houses). The roof top chords can be extended from the two outermost column rows to make canopies that protect the front veranda as well as the back wall from sunlight and rain. When the house owner wants the veranda to be larger, a row of columns (called veranda columns) may be added to support the extensions of the top chords. For the two gable walls, the roof can also be elongated and these two eaves are supported by the top chords and girders. The roof may cover and thereby protect the gable walls from rain water leakage. This is an equally effective cooling solution for a house in such a hot and humid tropical country like Vietnam, as it helps to minimize solar radiations (see Fig. 5).

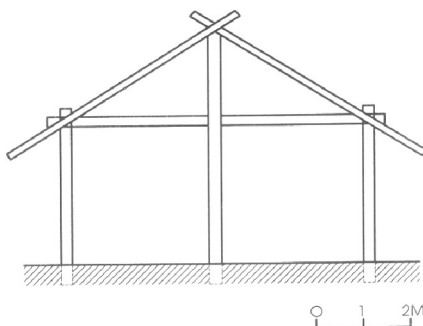


Figure 5. Three-column truss system [2]

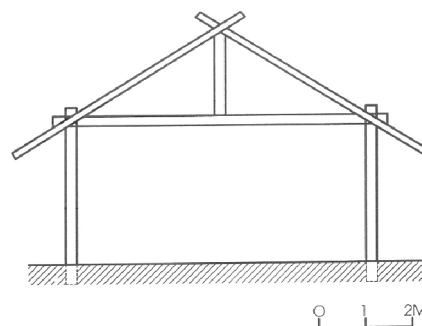


Figure 6. Transversal-beam truss system with two columns and a post in the middle to the ridge [2]

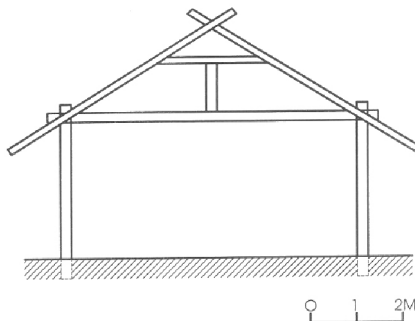


Figure 7. A transversal-beam truss system with a T-shaped post in the middle [2]

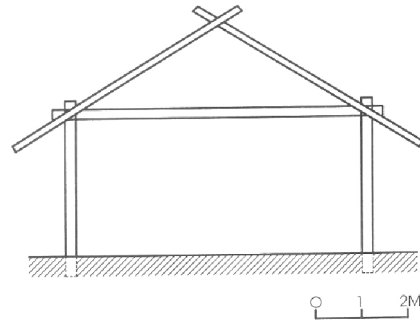


Figure 8. A simple transversal-beam truss system (without a post in the middle) [2]

A transversal-beam truss with two columns and a post in the middle to the ridge: This truss system is a variant of the three-column truss system, because the use of a larger and more flexible indoor space needs to be taken into consideration. As a result, the middle column (main column) should be removed. There is only one post in the middle of the truss leaning on the cross beam. This post is regarded as the remaining part of the so-called hidden column. The two columns in the front and in the back are firmly fixed onto the ground. The length of the cross beam is the same as the width of the house (see Fig. 6).

A transversal-beam truss with a T-shaped post in the middle: This truss system is a transformation of the above-mentioned type. In order to improve the load-bearing capacity of the truss, the middle post should not reach the ridge but ends up with a horizontal bar that joins the two top chords of the truss together. The two columns in the front and in the back are also firmly fixed onto the ground (see Fig. 7).

Simple transversal-beam truss (without a post in the middle): This truss system is the simplest type, comprising two columns firmly fixed onto the ground floor. In this case, the two top chords and the cross beam all lean straight on the tops of the two columns. The cross beam works as a bracing that joins the tops of the two columns together (see Fig. 8).

Among those four types of bamboo truss, the transversal-beam truss with a T-shaped post in the middle has the most aesthetic value, highest technical installation requirement as well as the longest span.



4. Binding methods for a bamboo truss

4.1 Binding with strings

In case of simple houses, temporary houses and cattle/poultry breeding facilities, strings are used. For traditional houses, where a higher level of structural stability is required, a combination of fastening dowels and strings is usually chosen.

4.2 Strings used to bind bamboo components together in traditional houses are often made of the following materials

- Rattan strings: The main part of rattan plants is split and made into strings at a particular length. Rattan strings are dried in the kitchen (above the oven). Before use, they should be dipped into water in order to regain the elasticity of rattan strings;
- Bamboo strings: Bamboo trunks are split into thin strings. Just like rattan strings, bamboo strings are elastic, and should be put into water before use for easier binding.
- Ropes: these are cords woven from jute strings, ready and easy to be used for binding purpose. However, they are not so often used in fact, because they will become dry and broken only after a few years;
- Iron wires: these are wires, 2 to 5 millimeters in diameter, used to bind components in houses together. However, iron wires were difficult to be produced in the past and easy to be oxidized, thus they were not often used in traditional houses. So there were only two main types of strings in building traditional houses: rattan and bamboo.

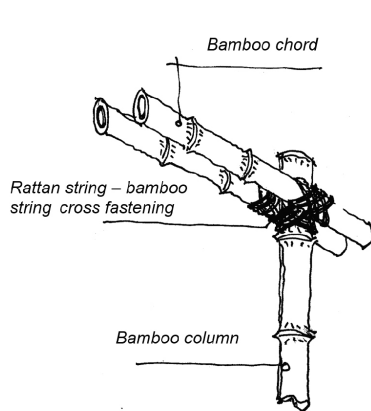
4.3 Methods for string binding

- String binding: using a bamboo string or a rattan string to cross-bind the components twice, then fastening the components with a knot (see Fig. 9).

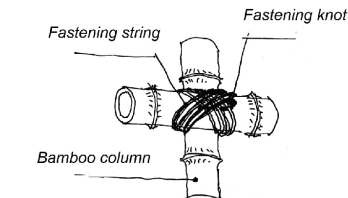


- Fastening string-wedge/nail binding: using a bamboo string or a rattan string to cross bind the components twice, then fastening the components with a knot and a small bamboo bar with one pointed end as a wedge or a nail to firmly fix the binding by means of tension of strings (see Fig. 10).

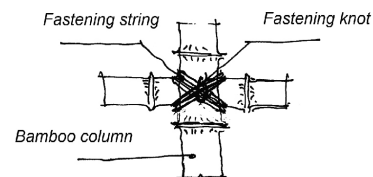
- Fastening string-bamboo dowel: a double cross binding method applied to components. The two ends of a string are tied up together and then bound with the upper part of one bamboo dowel (30 to 40 centimeters long, made of the hardest part of a bamboo trunk). This bamboo dowel should be rotated by hand one or two full circles, until the string is tense and the components are tightly fastened up. Then another string should be used to fix this bamboo dowel onto the main part of the components, such as a column shaft (see Fig. 11).



a. Fastening string cross binding



b. String binding type 1



c. String binding type 2

Figure 9. String fastening binding

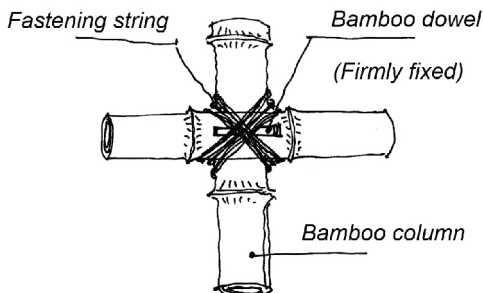


Figure 10. Fastening string-wedge binding

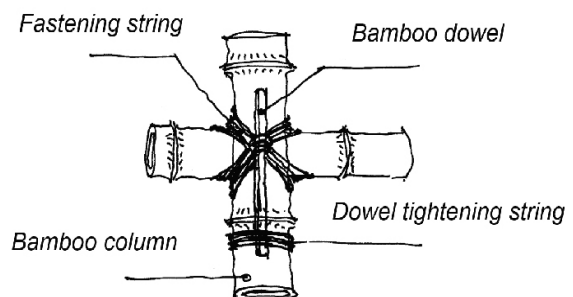


Figure 11. Fastening string-dowel binding

4.4 Dowel binding

A dowel here is a hard piece of bamboo, straight and may be 30 to 40 centimeters in length, depending on the number of components to be bound together. It is necessary to use a chisel to make a hole through a bamboo trunk. The diameter of this hole is slightly larger than the diameter of the bamboo dowel, just 2 to 3 millimeters, so that this bamboo dowel can be easily put into the hole. The horizontal bamboo dowel should be driven across all the components. In order to firmly fix the binding, a rattan string or a bamboo string can be used to tie up all the components. Thereby a component may not become loose from the horizontal dowel binding (see Fig. 12).

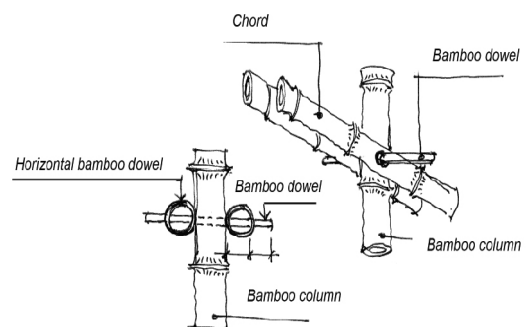


Figure 12. Bamboo dowel binding



5. Application of bamboo in modern architecture

Nowadays, in order to protect the natural environment and respond to the on-going climate change, buildings should be environment-friendly, green architecture can be achieved by applying a variety of mea-

asures, including using green materials. Many architects have been aware of the values and meanings of using bamboo, and they keep on using this material in modern architecture creatively. They have succeeded in designing a large number of green buildings with bamboo. Their buildings do not only show creativity, but also highlight sustainability. These architects have made a significant contribution to the protection of human living environment.

In modern architecture, bamboo seems to be the most appropriate building material for various types of architecture (as shown in Table 1). At the same time, bamboo can be best used for the fabrication of building components (trusses, columns, floors, walls, roofs, decorative details) and other interior furniture (tables, chairs, beds and wardrobes). In addition to binding methods such as bamboo strings and bamboo dowels, iron is quite often used for binding bamboo components in modern buildings, with various options: iron wire, iron pins/dowels, iron belts and iron bolts. The two types of joints in traditional and modern architecture demonstrate great potential in bamboo utilization for modern buildings (see in Table 2).

Based on the results of the comparison above, it can be seen that bamboo has been used widely in modern architecture with diverse types of architecture and combine binding methods compared with traditional architecture.

For application in modern architecture, bamboo is well treated against insects and decays in a traditional way (without chemicals) in order to maintain and maximize the natural characteristics of bamboo. Bamboo is kept in mud, then fumigated and heated, so that it can be bent into ideal curves to form the desired bamboo frames. After being treated and shaped, bamboo is installed into the position of the structure as designed. For example, using as columns, bamboos are formed into square, rectangular, elliptical or circular bundles (with steel core if necessary). The bamboo bundles are tightened with rattan strings or steel bolts (should be reduced as they can affect the connection between the bamboos); In case of being used for beams, bamboo canes are tightened into bundles, put up on column structures or bent into curved beams (see Fig. 13); for being the walls, floor or roof, bamboo canes are formed into layers (at least two layers), combining with steel beams or wooden beams to support the roof or the floor. Connections between bamboos are mostly tightened with rattan ropes and bamboo bolts, which could be further developed and promoted from traditional connections into the main solution in modern architecture. In several buildings, bamboo is used as material for columns and trusses which are shaped according to the ideas of the architect and in accordance with the form of space used for the project, while using connecting as cording and latching of traditional architectural style (see Figs.14 and 15).

In addition to many advantages such as being a local, natural and friendly material, which is easy to be exploited and used, bamboo is also simple to be shaped and combined with all other materials in

Table 1. Comparison of the use of bamboo in various types of architecture

Type of building	Traditional architecture	Modern architecture
Housing	X	X
Resorts	0	X
Communal houses	0	X
Kindergartens	0	X
Schools	0	X
Service buildings in tourism	0	X
Restaurants	0	X
Buildings in entertainment parks	0	X
Play facilities for children	0	X
Interior furniture	X	X
Village entrance gate	X	0
Cattle/poultry breeding facilities	X	0
Agricultural factory	0	X

Note: X: usable; 0: no-use

Table 2. Comparison of methods of connecting bamboo components in different types of architecture

The method of connecting bamboo components	In traditional architecture	In modern architecture
Bamboo strings	X	0
Rattan strings	X	X
Iron wire	0	X
Rattan strings with iron wire	0	X
Steel bolts	0	X
Bamboo dowel	X	0
Iron dowel	0	X
Bamboo with steel core	0	X
Iron bolts	0	X
Combine binding methods	0	X

Note: X: usable; 0: no-use



Figure 14. Vietnam Pavilion Kontum Indochine Café [4]

Figure 15. Image of bamboo trusses in Suoi Re Communal house [5]

Using bamboo in the modern architecture and construction is undoubtedly appropriate for developing countries and regions that are facing climate change, flood and sea water level rising. Bamboo will still be useful in the future, as far as its values are concerned.

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