

# Bamboo as a Low Impact Construction Material

## A research on bamboo architecture in Yunnan, China

Liwei Liu  
MA Architectural Design  
110204132



### **Introduction**

Bamboo as a building material has been used for a long time in Asian countries such as China, Vietnam and Thailand, also it is widely used in Latin American countries as well, and is now making its way to the western world, too.

Bamboo is a prime example of sustainability - with respect to both the plant itself and its use as a building material. Bamboo has been tested to perform under compressive and tensile strengths comparable to traditional dimensional lumber wood species and its light weight means that it performs better in shear than materials of greater mass, like concrete. Shear forces are in play during adverse events like high winds and seismic activity. (Toolbase.org) A further

advantage of bamboo is that in many cases environmentally damaging transport is unnecessary, since bamboo grows “on the doorstep”. What is more, building of bamboo can be easily recycled or dismantled and it is easy to replace individual components - such criteria have only recently emerged in Western architecture and are often difficult meet using conventional materials.

This article will firstly demonstrate an overview of bamboo as architectural material used in building construction mainly in Yunnan Province of China in both historic and contemporary aspects. Then it will discuss the applicability and appropriateness from the different influence-elements in the purpose to generate the judgement of whether bamboo is appropriate for building material in the local area? To the end, I will make a brief conclusion to the question I make and give some advices on the bamboo material development based on the research result I acquired.

### **Bamboo as construction material**



Source: Vitra Design Museum

As a giant grass, bamboo can grow up to 4 feet in one day. It is highly renewable because the stalk can be cut like grass and leave the roots in the earth to regrow another forest. Bamboo has other advantages in the aspects of sustainability, construction, aesthetics, etc. Bamboo is a traditional construction material that has a much lower price and production compared with timber material. The growing time for timber is 20 - 40 years, while in terms of bamboo the time is

around 4 years. Moreover, the productivity of bamboo is 3 times higher than timber. As a growable material, the supply of timber material is strictly controlled by the government because of the consideration of environment and status of the forest. This situation leads to a result that the price of timber is relatively more expensive than bamboo. The mechanical plasticity of the bamboo is stronger than wood so it has a better flexibility and can be used to create large quality of structural systems, that means the physical and spatial form of architecture can be more diverse by using bamboo as load-bearing and frame construction material. According to forecasts, the future demand for wood in Asian countries will far exceed supply. In order to prevent this leading to even more rapid destruction of the rainforest, China is working to develop a national program to promote the use of bamboo as a substitute for tropical woods - a scientific approach of global significance. (Vitra Design Museum)

On the other hand, bamboo is still widely used in temporary construction instead of common building like concrete and steel in modern buildings. It is mainly because the material itself, compared to wood, is less durable and seems to be easily deformed in original state. And bamboo contains carbohydrates, fats, proteins and other organic substances that are the feeding nutrients for insects and germs, which might lead to infestation and rots. Through the treatment of high-temperature water, bleaching and carbonizing the problem of insect and germ infestation can be solved appropriately. Also, integrating bamboo material with high-quality, environment-friendly agglomerant and high-pressure curing process could solve the transmutation. These pretreatments can transform bamboo into an efficient and reliable construction material for more comprehensive projects - even for long-span structure system.

### **Historic and vernacular use of bamboo in Yunnan Province, South China.**



China has a long history of bamboo construction. It is recorded that bamboo building in ancient times is widely used, such as housing and garden landscape building. The bamboo house is extremely cheaper than the timber or brick houses, so low-income in rural areas used bamboo as the main construction material for their houses. As Buddhism entered China, more and more temples were built with bamboo, these temples were called bamboo courts. Other religious architecture such as bamboo palaces, bamboo ancestral halls were widely built as well.

Not similar with the common traditional architecture constructed by wood, in Yunnan Province the local Dai people use bamboo as their housing material for

more than 1400 years. Yunnan Province is in the southwest of mainland China, the climate is warm and humid with an average temperature of 21°C. The area that has no distinction between 4 seasons is covered by large amount of tropical rainforest and has abundant rainfall annually. One of the largest natural local resources is bamboo, so the people who live in the flat area transport the bamboo stalks to their residential area to construct their houses.

Stilt houses is the most used style of architecture in the vernacular area. The main body of the building is raised on piles over the surface of the soil or water. The main reason for this is to avoid the humid ground and water environment as the area has abundant rainfall amount. Also the architectural style can keep out vermin where is common in tropical area. The main construction material for stilt house is large green bamboo, one of the main bamboo species. Thick stalks are made for bearing system including columns, beams and roof trusses. Bamboo slices are weaved to be walls. Cut stalks are flattened to form the floors. Additionally, doors and windows are all made by bamboo. The roof is covered by thatch, palm leaf row or tiles made by cut stalks.



Source: <http://www.landscape.cn/News/Ecology/2012/4/7757710919212.html>

Since the greatest disadvantage of bamboo lies in its susceptibility to damage by insects and fungus, numerous methods have been developed to protect bamboo. In addition to immersion, these methods include coating with lime slurry, heating, or smoking, which can provide protection as well. As early as the 16th century, people in Asia developed a system of smoking bamboo to protect the material.

## Contemporary use of bamboo

In the contemporary time, bamboo is one of the plants most used worldwide. It forms the livelihood of over one billion people, mostly in rural areas in poor, developing countries. Approximately 1,300 varieties of bamboo spread across 75 species cover about 25 million hectares in tropical and sub-tropical regions, and around 10 per cent of temperate zones. (W. Liese) Potentially, bamboo can be the material for most parts a building. After professional and scientific pre-treatment, the bearing ability, durability, fire resistance of bamboo can be greatly improved.

Now bamboo industrialization level in China is in leading position among worldwide. Engineering materials and decorating materials such as laminated bamboo, bamboo plywood, bamboo glulam, etc. The main components and connecting joints can be pre-processed in factory than the assembly on site is faster than other structures since large construction machinery is not necessary. Bamboo can be used in many parts of building: at the foundation stage bamboo can be used for making trusses, moldboards, bridges and tunnels. Bamboo can replace the role of steel boards and timber blocks in building construction. Furthermore, in external decoration and interior design stage, bamboo can be used as external wall, decoration wall, external floor, thermal wall, etc. Also the utilization of bamboo material in gardening and landscape architecture is playing an important role in the the design project. Pavilion, bridge, and pergola made by bamboo are very common in Chinese gardens.



The main usages of bamboo in architectural industry are differed into 3 aspects. Firstly, bamboo canes are often used as construction scaffolding. Other large, open, and exposed constructions (e. g. Breakwaters, pipelines, bridges, roofings ) are also common. The bamboo scaffolding used in the expansion of Chinese cities in booming speed is highly spectacular. In large cities such as Shanghai and Kunming(The capital city of Yunnan Province) the scaffolding can be up to 200 metres. Compared to steel scaffold which is common in Europe, bamboo scaffolding has better performance in windy climate. This structure mainly consists of a system of large quantity of single canes. While the radius of bamboo canes differs much from cane to cane, and from up to bottom. This lead to a more comprehensive progress of assembly

and disassembly. Another usage of bamboo in architecture is moldboard for construction cement. This technology developed for 30 years uses mat and curtain made by bamboo as original material and involves procedure such as dipping, drying, and heating Multiple bamboo boards. Compared with steel moldboards and plywood moldboards, bamboo moldboards are lighter and cheaper. Heat resistance and stability of the bamboo moldboard is also outstanding. Additionally, using bamboo moldboard tend to be easier to get smooth and flat surfaced components.

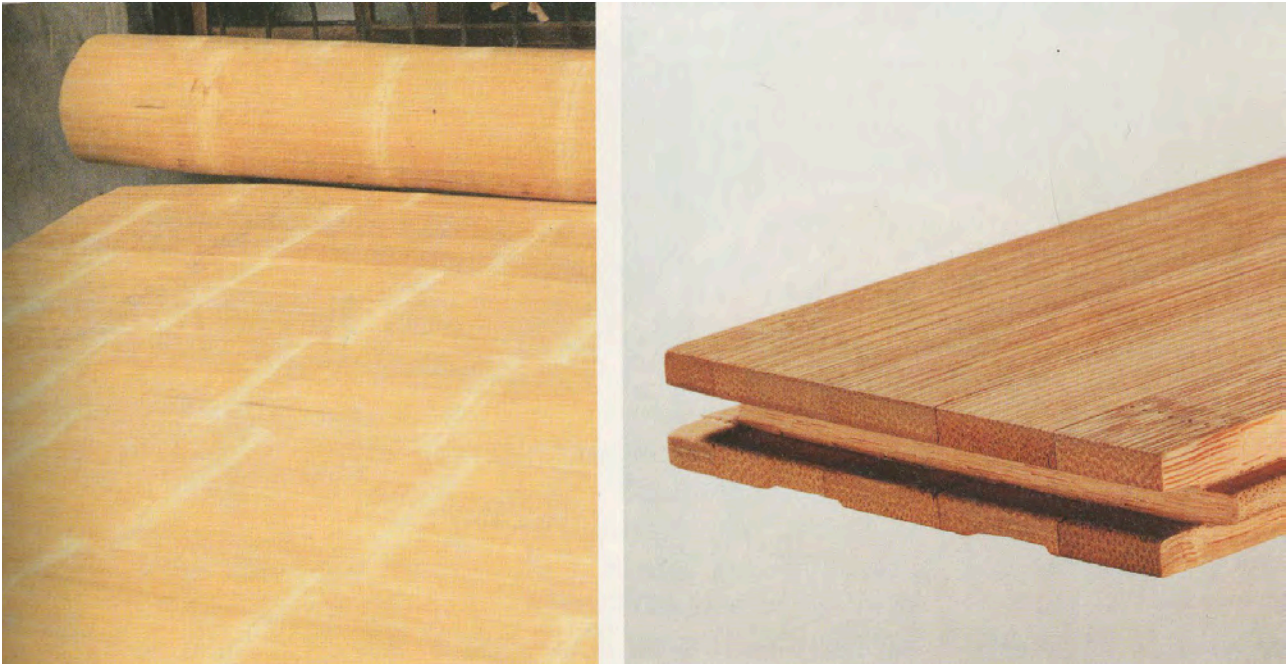
Bamboo as a structure and construction material in house building is still common in rural areas. Bearing components such as columns, beams, trusses are formed of thick canes. Roof, ceiling and walls are made by sliced bamboo. The connecting joints that support the bamboo slices are thick bamboo or timber. To strengthen the performance of thermal and noise insulation, the bamboo wall is coated flatly with cement. One advantage of this houses is that the material treatment is easy and building cost is low. However this system of bamboo is only appropriate for simple structure and low level building because of the natural limitation of raw bamboo such as different radius of canes and the bearing ability of bamboo itself.

To built houses with better quality and fit the higher criteria, raw bamboo canes can not be used as bearing and framing system components any more. One reliable treatment of raw bamboo canes is laminated bamboo manufacturing technology. Firstly, select large-diameter bamboo species as the raw material and split the canes into thick slices, then follow the procedure of softening - flattening - dehydration - sizing - piling - heating - lamination to produce the pre-treated laminated bamboo battens. This laminated bamboo is believed to be capable to replace the traditional timber in a proper condition.



In Yunnan Province, China, new stilt houses are still built in the rural area by local inhabitants. Bamboo makes for an wonderful support, since it has an inherent stiffness owing to the natural subdivision into individual segments. "As bamboo is susceptible to ground moisture and insects, bamboo supports are often fitted with feet of stone or concrete to protect them from direct contact with the ground. "(Vitra Design Museum) Many ways of making walls by bamboo are used by people in different areas. Although the easiest method is to create a block or palisade

wall of vertically arranged - whole canes, alternatively bamboo canes split into strips form an important building element for wall structures. Furthermore, many Japanese architects are developing and exploring new approach of transforming the traditional material into a modernized high-performance material. Filling the skeletal structures with concrete to make bamboo more capable of bearing load is more and more common in architectural design and practice.



### **Precedent: Green design based on bamboo in Yunnan, China**

The International Network for Bamboo and Rattan (INBAR) ([www.inbar.int](http://www.inbar.int)) and WWF China ([www.wwfchina.org](http://www.wwfchina.org)) have jointly launched the project "Promotion of Energy Efficient Buildings: Integration of Bamboo and Renewable Energy Technologies" in March 2002. The objective of the project was to design model houses, hotels and school buildings for south western China, particularly in Yunnan Province where abundant bamboo resources are available and which has a tradition of using bamboo as a building material. Because of the climatic variations in Yunnan, one should take the different local conditions into consideration and use the available resources.



*Pingbian (Yunnan) school under construction. Source: Tang Di*

One of the projects that has been finished is the Pingbian school. The elementary school is used by 200 students and 14 teachers. The original construction is based upon concrete columns and beams. This open construction would have been filled with floor elements based on laminated bamboo beams and flooring with bamboo plywood. The space between the columns was to be filled with bamboo-frame elements. The basic construction is the same as the Canadian wood-frame (platform) construction method.

Unfortunately the certification of the different bamboo products was not finished in time and the amount of bamboo used in this design decreased. One building block has bamboo wall panels and a bamboo roof construction by means of an experiment. Because of the climatic circumstances the building construction needs to be insulated for cold winter days. At the same time big south windows will warm the classrooms. A very heavy and massive construction is not necessary because of the semi-mountain climate with moderate winters and warm summers. For that reason, sunshades and overhangs are useful and an insulated building is necessary.

(Tjerk Reijenga)

## **Appropriateness of bamboo construction in Yunnan**

### **1. Climate and availability**

The main characters of the climate of Yunnan Province are warm, rainy and humid. The annual average temperature is 21 °C. So that the traditional house type of stilt house is proper for the vernacular climate. The average temperature is comfortable so there is no strong demand for thermal and protection from heat. While the main concern of the local people is to avoid the humid ground. The Dai area in Yunnan has an abundant rainfall amount which means the moisture on the ground level of a ordinary house is relatively higher than the



other areas in China. Bamboo houses have much lighter weight than the traditional and typical timber/brick structured houses in North China. So that raising up the building away from the humid ground needs a less strong bearing column system. Also, 24% of the dimension of the area is covered by forest, building houses by local timber or bamboo will save a large amount of budget for the transportation of material. Bamboo in Yunnan has a large productivity among the local plants, and the growing speed and productivity is much more considerable than timber. To be advance, the walls of stilt houses are covered by weaved bamboo strips. The gaps between the strips make it possible to let wind blow into the indoor space, which can be considered as a pattern of passive ventilation.

## 2. Other use of bamboo

Bamboo also can be used for the manufacturing of window and door. But the traditional function of windows and walls in tropical bamboo houses is mainly to enhance ventilation and the presence of natural light inside. In ancient China, bamboo slats were use as paper - just like parchment in historical Europe. Bamboo slats were soaked in vats of water first, then comes dehydration and pressure. The same technology of paper manufacturing can be seen in ancient time of Egypt as well. (Using Papyrus) What's more, bamboo rafts are common transportation type in the river covered Yunan area.



## 3. Impact of climate

Since bamboo has a strong adaptability to different climate, it is believed that bamboo as a material itself would not be easily changed in physical quality. Also, the Dai area of Yunnan is close to the edge of tropical area and locates in the warm and flat rural area in mountain district, so that bamboo as a main structural material is excellent for the local people in consider of strength and budget reason.

## 4. Environmental impact

“A comparison of the energy balances of various building materials (in other words, the energy required to produce a unit of a building material with a certain level of load-bearing capacity) gives an idea of the sustainability of bamboo:

|           |       |
|-----------|-------|
| Concrete: | 240   |
| Steel:    | 1,500 |
| Wood:     | 80    |
| Bamboo:   | 30    |

(Units: MJ/m<sup>3</sup> per N/mm<sup>2</sup>; from J.A. Janssen; Bamboo Research at the Eindhoven University of Technology, Eindhoven 1990, p. 15)” (Vitra Design Museum)

Building a bamboo structured house in Yunnan needs 40 m<sup>3</sup> while using the common brick and concrete building will consume large amount of coal along with a destruction of farming lands. The new type of bamboo house could make the base cement or timber structured whilst the other parts of the building could be made of bamboo material, which can decrease the consumption of timber tremendously. It is estimated that if 1,000,000 families (1/4 of the ethnic minority in Yunnan ) live in bamboo houses, 40 million m<sup>3</sup> of timber and 360,000 hm<sup>2</sup> can be protected from destroyed.

As Yunnan has a large local production of bamboo, the transportation cost can be lower than other areas where bamboo is not a main plant species. Also, bamboo is a excellently renewable material that can be harvest for several times in one year. The sustainability of bamboo as construction material in Yunnan is considerable.

### **Discussion: mutual influence between vernacular tradition and low impact response**

The Dai district in Yunnan province is basically isolated with the outside society and had its own culture. The location of the area and local bamboo production and the local residents till keep a tradition inhabit style of “building stilt houses and live beside water” - a living habit inherited from their ancestor. A merge and combination between different ethnic people in the following time led to a modification of living style. However the using of bamboo as housing material has not changed for over 1000 years. It can be inferred that bamboo construction in the vernacular area is still because of the low cost of collection and transportation. As modern technology bringing more development in construction progress, it is convincing that bamboo building in Yunan will have a brighter future - this is not only a matter of sustainability and environmental respect, but also a conservation of ethnic tradition and cultural diversity.

### **Conclusion and proposal**

Bamboo as a sustainable and low impact material in architectural construction can play a more important role in the future. The traditional and contemporary methods of building structures by using bamboo has a terrific reason to be introduced and spread to more areas. In Dai district, Yunnan, China, where the climate is perfect for growing large quantity of bamboo it is appropriate to involve more new technology to renew the bamboo structure and construction process. While the bamboo building, which is limited under 3 floors in height, and a relatively small scale, tend to fit the demand of rural areas rather than urban developing.

## **Bibliography**

Vitra Design Museum. 2000. *Grow your own house: Simon velez and bamboo architecture*. Weil am Rhein : Vitra Design Museum.

T. Reijenga. '*The Role of Bamboo in Green Building Design*.' BEAR Architecten.

Wenju. Li & Jia. Li. '*Recycle Way of Bamboo Building*.' *Huazhong Architecture*. Vol. 26. (10/2008)

Zhan Chen & Sanming Zhang. '*The Passive Techniques About Energy Efficiency in Chinese Traditional dwellings*.' *Huazhong Architecture*. Vol. 26. (10/2008)

Yuming Yang, Kanglin Wang & Zhongwen Yin. '*Practices and Development of New Bamboo Building*.' *Journal of Bamboo Research*. Vol. 23. (2/2004)

Structural Bamboo, Green Building Elements. <http://greenbuildingelements.com>  
[Accessed 27 May 2012]

Toolbase.org. <http://www.toolbase.org/Construction-Methods/Wood-Framing/structural-bamboo>[Accessed 27 May 2012]