

Bamboo envelope in Chinese dwelling toward ecological sustainability

เปลือกอาคารไม้ไผ่ในบ้านพักอาศัยของจีน
เพื่อความยั่งยืนของสภาพแวดล้อม

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บทคัดย่อ

จีนมีประสบการณ์ที่สะสมกันมายาวนานในการใช้ไม้ไผ่เป็นเปลือกอาคาร เทคนิคการก่อสร้างอย่างเช่น การสานและฉาบผนังถูกใช้กับส่วนประกอบของอาคารในพื้นที่ทางใต้และตะวันตกเฉียงใต้ของจีน ในปัจจุบันที่วัสดุก่อสร้างอาคารสมัยใหม่ได้ก้าวเข้ามามีบทบาทกับชีวิตประจำวันของผู้คน แทนที่วัสดุแบบดั้งเดิมและวัฒนธรรมชาติ ดังเช่นไม้ไผ่ ซึ่งส่วนมากใช้เพื่อเป็นพื้นผิวของที่พักอาศัยในอดีต โดยมีประโยชน์ในแง่ของการเป็นมิตรกับสิ่งแวดล้อมและราคาย่อมเยา ดังนั้นงานวิจัยนี้ได้สำรวจและวิเคราะห์วิธีการใช้ไม้ไผ่เป็นพื้นผิวของอาคารด้วยวิธีการแบบดั้งเดิมและวัสดุสมัยใหม่ ผ่านกรณีศึกษาและการศึกษาภาคสนามในพื้นที่ทางใต้และตะวันตกเฉียงใต้ของจีน การวิจัยนี้หวังที่จะแบ่งปันประสบการณ์ที่มีประโยชน์และให้ความรู้สำหรับผู้ที่ใช้วัสดุจากไม้ไผ่ในการก่อสร้างที่พักอาศัย ให้สอดคล้องกับระดับเศรษฐกิจของแต่ละคน

คำสำคัญ: เทคนิคการก่อสร้าง, บ้านพักอาศัยแบบจีน, เปลือกอาคารไม้ไผ่



Abstract

China has extensive experience in using bamboo as an environmentally friendly and economical material to construct a building envelope. In the past, construction components like wattle and daub wall were used in the south and southwest regions. Recently, however, modern building materials have replaced traditional and natural materials. The present article investigates and analyzes traditional and modern methods of using bamboo as a building envelope through case studies and fieldwork in south and southwest China. It is intended to shed light on valuable experience for Thais who could use bamboo material to build their houses.

Key words: construction techniques, Chinese dwellings, building envelope

Introduction

China has a long history of using bamboo in constructing buildings, which has led to diverse architectural styles, craftsmanship quality, and techniques. In the past, bamboo was widely used as a construction material in the south and southwest, where the weather and soil are suitable for the growth of many giant species. Later, as urban and rural housing circumstances changed, the role of bamboo in construction decreased.

Currently, however, new bamboo materials have been developed in China and some people have begun to use them in their dwellings. In Thailand, local Thais also have experience in using bamboo wattle and daub wall as envelope, but the techniques are not widespread, skillful, or attractive. Thus, an examination of both modern products and traditional methods of bamboo usage in China will provide some insight into designing and constructing rural dwellings.

Objectives, methods and scope

The study is intended to investigate and analyze the efficient usage of bamboo as an envelope¹ in Chinese dwellings.² It aims to identify appropriate and affordable construction materials that can be applied to Thai rural areas to lower the construction cost of farmers' dwellings. At the same time its use can reduce dependence on industrial materials, result in minimal harm to the natural environment, and encourage sustainable development of local resources. The research incorporates case studies, fieldwork, interviews, and a literature review.

Case studies of investigation include Jingdai village (景代) in Xishuangbanna (XSBN), Kunming³ (昆明) of Yunnan province (云南省), and the Nanxijiang (楠溪江) area in Zhejiang province (浙江省).

Jingdai village is located in Mengzhe district (勐遮镇), Menghai County (勐海县) of XSBN, Yunnan Province (*Figure 1*). It is situated between the north tropical and the south sub-tropical climate zones, with a long summer and no obvious winter. The amount of sunlight is 1800–2300 hours annually. The average temperature is 18.7°C. Annual average of rainfall is 1341 mm.

¹ The term, building envelope, refers to exterior surfaces that enclose the internal space of a building. The building envelope includes all external building materials like walls, windows, doors, and the roof. It serves as the outer shell to protect the indoor environment as well as to facilitate its climate control.

² The term, dwelling, generally refers to a building designed for living.

³ In this paper, the Yunnan Minorities Garden (云南民族村) and the World Gardening Expo (世界园艺博览会) are regarded as case studies in Kunming municipality.



Figure 1. Jingdai Village, Mengzhe County, Jinghong, XSBN, Yunnan Province

Jingdai is a Dai minority village. It was built about 300 years ago, and now has 800–900 residents. About 97 percent of the villagers are Dai, while the rest are Han. Among the minority groups in China, the Dais are famous for their long history of using bamboo. The village is also well known for its octanglar pagoda, which attracts many tourists. At present the villagers earn their living by growing rice and tea. Most of them use small tractors for cultivation. Space under the house is seldom used for keeping animals as it was in the past.

Nanxijiang⁴ is famous for its beautiful landscape, old town area, and villages. It is located in Yongjia County (永嘉县), Wenzhou (温州), south of Zhejiang province (浙江省). Its sub-tropical marine monsoon climate has sufficient sunlight and abundant rainfall, with four clearly-demarcated seasons. The annual average temperature is 18.2°C. Formerly, local people were skilled in using bamboo as a building envelope in the wattle and daub technique (*Figure 2*), which later became the identifying feature of local dwellings.

⁴ Nanxi is the name of a river (Jiang-river) in Zhejiang province surrounded by mountains and natural forests. Along the sides of the river are old villages that have a long history of human settlement and a rich local cultural heritage.



Figure 2. Nanxijiang traditional style dwelling

Investigation and Discussion: Traditional Bamboo Application

Previously, Chinese villagers realized bamboo's value as an architectural material. They used a great amount of bamboo materials in constructing dwellings, especially in southern China's Ganlan⁵ style. Many types of bamboo envelope were produced according to climate, local resources, construction skills, esthetic requirements, cultural preferences, and so on. In general, traditional techniques can be divided into four categories.

(1) **Bamboo wattle and daub:** In this type of wall (*Figure 3*), bamboo twigs are woven into a wooden framework, followed by plaster mainly made of mud. Coarse fibers such as reed and hemp are added to improve the bonding strength between the bamboo and the mud. The surface is coated with lime whitewash to improve the building's appearance so that it resembles plastered brick walls. The lime coating also improves its acoustic quality, durability, and ability to resist fire (*Figure 4*).

⁵ Ganlan dwelling: A building for living purpose that is constructed on piles with raised floors to avoid excess dampness or dangerous animals. This type of dwelling is built primarily in southern China, which has heavy rainfall and high humidity.



Figure 3 (left). Wattle and daub wall in a Nanxijiang dwelling

Figure 4 (right). Bamboo wattle and daubed wall, Zhejiang Province

Today, this type of wall is found in the dwelling styles of both Han nationality and some minorities,⁶ distributed among Anhui, Zhejiang, Fujian, Guangdong, and Sichuan provinces. Apart from dwellings, minority groups in Guizhou and Guangxi provinces build their houses with wooden post and beams, while bamboo wattle and daub is used for the walls of granaries.

(2) Woven bamboo: For the humid climate in southern regions, heat preservation is not a primary concern. Therefore, bamboo woven wall is used for both envelope and partitions (*Figures 5, 6*) while well-off farmers usually use wooden planks. However, woven bamboo wall needs to be replaced every two to five years because it easily gets mouldy in the rainy season and rots from the sun's heat in the summer. Woven walls are found mainly in minorities' dwellings in the south, such as the Dai dwellings in Dehong autonomous region (XSBN), Yunnan province.

⁶ Han and minority style dwellings are defined roughly. In the author's view, through migration and other factors, the blending of culture and construction techniques are shared from time to time. The various ethnic groups also adopted knowledge of construction techniques and technologies according to local conditions and available materials, resulting in imprecise definitions of style for each nationality.



Figures 5 and 6. Different style of woven bamboo as envelope by Chinese minority buildings.

Traditional style dwellings commonly do not have ceilings; those that are present are normally made of bamboo matting.

(3) Vertical and horizontal culms: Walls may be built with full, half, or beaten flat bamboo culms, which are arranged close together vertically or horizontally (*Figure 7*). The simplest technique is one in which entire bamboo canes are arranged vertically, allowing rainwater to flow away quickly with less decay than in a horizontal arrangement.



Figure 7. Installation of bamboo wall using horizontal culms.

(4) Bamboo strips: This technique is usually found among Chinese minorities. Bamboo strips are more popular than half and full culms. They are often used for wall, door, window, and flooring materials of Dai dwellings in Jinghong (Chiang-rung) Autonomous Region of Yunnan (*Figures 8, 9*). As with the above-mentioned techniques, good interior ventilation can be achieved by leaving small gaps between each strip. The disadvantages, however, are that cool air easily flows in during winter and mosquitoes can enter in all seasons. Poor acoustics and lack of privacy are other unpopular features. As with culm techniques, vertical strips are preferable to horizontal ones regarding rain drainage.



Figures 8 and 9. Bamboo dwellings in Man Jing Bao, Jinghong, Yunnan

For flooring, flattened bamboo, woven bamboo, strip bamboo, or small culms are fastened to the floor frame by lashing, nails, thongs, or wire. A bamboo log 100 mm in diameter produces a flattened bamboo strip about 320 mm wide. Fieldwork in Jinghong indicates that sometimes two layers of bamboo strip are laid transversely to each other in order to support a heavier vertical load.

The Application of Bamboo with other Materials: A Case Study of the Nanxijiang Area

In practice, bamboo material is usually used in construction with other local materials. In Yantou (岩头), Furong (芙蓉), Linkeng (林坑), and the villages of the Nanxijiang area, villagers mainly use stone, wood, and bamboo to build their dwellings (*Figure 10*). The foundations are made of stone while woven bamboo wattle and daub are used for the walls. Each side of the walls is divided into smaller panels by wooden frames, which help to reduce cracking. The thickness of daub is about 1 centimeter. After it is dry, white lime is applied to the surface to ensure a clean and bright appearance. Commonly the proportion of daub components is not fixed; so farmers generally mix some straws with mud and lime together, which helps to increase tension strength. The wattle and daub technique can protect bamboo from fungi, mold, wear, and oxidation. The white walls look simple and elegant against the bright blue sky and contrast with dark brown tiles, creating a beautiful landscape that is the hallmark of Nanxijiang identity. This method of bamboo usage is ecologically friendly, economical, and practical. Villagers can afford to build their dwellings by using bamboo and other local resources. Moreover,



Figure 10. Furong Village, Nanxijiang, Zhejiang Province

people seldom consider this kind of dwelling as a symbol of poverty compared to concrete buildings in the same villages.

Application of Modern Bamboo Materials: Field Work in Kunming

With modernization, the use of architectural materials must be adapted to changes in living patterns and the social environment. At present, some minority groups in southern China, especially the Dai, have begun to use reinforced concrete and brick to build their dwellings. In their view, bamboo represents poverty; consequently, most of them would prefer to use modern materials, even if these materials are not suitable for their living environment. This change raises the important question of how to develop bamboo products and techniques suitable for modernization.

In 1991, a new bamboo material was used in the Yunnan Minority Garden of Haigeng, Kunming (*Figures 11 and 12*). The walls and floor were made of bamboo veneer board (竹编胶合板) that was produced locally. In 1999, the World Gardening Expo (世界园艺博览会) was held in Kunming and included a 400 square-meter bamboo museum. It was designed as



Figures 11 and 12. Contemporary buildings in the Dai Minorities Garden, built with bamboo walls.

a Ganlan stilt bamboo building and constructed using modern techniques. However the main building was made of pinewood because it had to bear the weight of many tourists. Processed bamboo was used for the envelope, ornament, and other building components. These included bamboo laminated board (竹层积材), veneer (竹胶合板), loop sandwich slab (竹环夹芯板), radial splice plate (径向拼接板), screw-cutting board (旋切板), section sheets (断面板), and strand woven bamboo flooring (竹丝板) (Figures 13, 14).



Figure 13. Laminated bamboo flooring (层压竹地板)

Figure 14. Modern bamboo flooring displayed in a department store

Although the Ganlan buildings in the World Gardening Expo are not used as dwellings, they provide examples of using bamboo products as envelopes in contemporary buildings. At present, the stability, safety of the load bearing framework, and the durable character⁷ of bamboo envelopes have exceeded the requirement of former materials. Their high elasticity, anti-impact property, and the wear resistance of floor and wallboard embody many excellent features, which have advantages over common wood. Moreover, their delicate patterns and color give them a modern, natural appeal.

⁷ Durable characteristics of bamboo include its moth-proof, mould-proof, anti-impact properties, as well as wear resistance.

Because the improvement of bamboo materials just has begun, they have not yet become popular among the Dai as they are expensive and are not commonly found in the markets.⁸

Dwelling Development and Attitudes to Bamboo: A Case Study of the Evolution of Dwellings in Jingdai Village

From our investigation, the revolution in dwellings in this village can be divided into three phases.

First generation: Timber and bamboo framework (before the 1980's). At that time, villages were isolated from outside communities but were rich in natural resources from the lush tropical rain forest. Bamboo and wood were easy to find. Accordingly, the stilt-raised houses of the Dai people were constructed of timber and bamboo, with thatched roofs of cogon grass. Bamboo was often used as the envelope in dwellings until the people could afford wood planks.

Second generation: Brick and timberwork (from the 1980's to the present). Houses retained the Dai style but appeared more massive and awkward because the ground floor was enclosed with brick and used as a storage room or kitchen. At this time, because of population growth, timber was not used for the structure, but only for doors, windows, and railings. However, many people still kept the kitchen on the second floor. During this period, most roofs were covered with concrete tiles.

⁸ From the investigation in some villages in the outskirts of Jing hong municipality, the authors seldom found dwellings made of modern bamboo products. In Manmai village, many contemporary dwellings are built of brick and concrete. In random interviews with twenty peasants, 95 percent said the new bamboo products were expensive and the local craftsmen lacked experience to apply them to local conditions. For these reasons, the villagers in Manmai were not familiar with new bamboo products.

Third generation: Reinforced concrete structure (since 2000). Through the influence of Western culture, dwellings are now built like those in the cities. The foundation is made of stone and concrete while the structure's mainframe is composed of concrete beams with brick walls and wooden windows. Roofs are sometimes covered with colored tiles and metal sheets, but only a small number of villagers can afford them.

At present, all three generations of dwellings still exist in Jingdai village (*Figure 15*), but examples of the old wood and bamboo style are few in number compared to the brick with wood frame style, which is the most typical. The third generation of dwellings is constantly increasing in number and in the future it will probably replace the second generation.



Figures 15. Three phases of the evolution of dwellings in Jingdai village

Local People's Opinions of Bamboo

In analyzing the development of Jingdai village dwellings, it can be seen that there is less use of bamboo envelope in the second and the third generations. Regarding this trend, the authors interviewed twenty villagers in July 2006 about bamboo's role in contemporary dwelling construction.

Their opinions about the disadvantages of using bamboo as an envelope are summarized below.

1) Moths can damage bamboo framework in a short period of time. Dirt between the gaps of bamboo panels is difficult to remove, while spiders like to spin their webs in corners. Consequently, occupants cannot easily clean dwellings made with a bamboo envelope.

2) Bamboo envelope is usually installed with a wooden frame for durability and load bearing reasons. Bamboo can be found locally but the supply of timber at present is decreasing.⁹ Thus, bamboo envelope is becoming less popular.

3) Nowadays, local people feel that only poor families live in a bamboo houses; those who are wealthier live in reinforced concreted buildings. Although bamboo dwellings are comfortable in a hot humid climate, people still do not want to build or live in this kind of dwelling.

Advantages of using bamboo in their view were the following.

1) Bamboo dwellings are earthquake resistant. They can survive an earthquake because of bamboo's high elasticity and the low mass of the

⁹ Increased population is the main reason. Long before, people used a great amount of wood to build their houses, which led to a shortage. Nowadays, a wooden house would be difficult for Dai people to afford.

structure. On November 6, 1988,¹⁰ a 7.6 degree earthquake struck Gengma county (耿马县) near the Lanchangjiang region (澜沧江地区), followed by 5 and 6 degree aftershocks. They left little damage to dwellings made of timber and bamboo, but most brick with timber frame dwellings were damaged with terrible cracks.

2) Bamboo and timber dwellings provide good ventilation and shading. Of course, by enlarging the windows of brick and timber buildings, ventilation theoretically can be improved, but the amount of heat-conduction becomes higher. In tropical regions, heat accumulates quickly in a short period and the temperature inside the house will increase sharply. Moreover, the heat that is built up takes a long time to dissipate. In contrast, bamboo is lower in heat conductivity than brick and timber and the temperature increases more slowly. This is the main reason that bamboo was once popular in hot and humid regions.

A villager, Mr. Yan, added that if the residents in Jingdai village were to build bamboo-timberwork houses, the construction cost would be higher¹¹ than those of brick and timberwork because the former requires a larger quantity of timber.

Insight from Fieldwork and the Case Study

At present, bamboo's role as a building material has undergone great changes. Traditional bamboo uses as well as modern products have both

¹⁰ Earthquakes occur occasionally in the Mekong region. Earlier, a 7.7 intensity earthquake struck on January 5, 1970 in Tonghai county (通海县) of Yunnan province. Mr. Yan Han (岩罕), a 60 year-old man, described the condition of dwellings in the village after the quakes.

¹¹ In 2006, villagers had to pay about 80,000-90,000 RMB for a two-storey brick-timberwork house (with a functional area of around 200 square meters), and 110,000-120,000 RMB for a three-story house of the same style.

advantages and disadvantages. Traditional bamboo material is ecological, low-cost, and energy efficient; but without being processed, its life span is short. Modern bamboo material is beautiful and durable, but it can consume more energy and resources in the production process, and even cause pollution. The price of innovative material is usually too high for common people's means. Thus, our fieldwork and selected case studies in China have provided us with some insight about ways to improve both traditional and modern techniques of bamboo usage.

The use of concrete block and pre-fabricated concrete components (such as flooring and walls) is popular and affordable for public buildings. But people in the rural areas should also think about their dwellings from the economic and ecological perspectives of how to acquire better living conditions by using local materials. Bamboo as an envelope material is different from industrial materials, because it is convenient to replace and its disposal does not harm the environment. So, the main issue is finding the best strategy for developing it.

From our case study analysis, we think that the development of bamboo materials should depend on standardization; for example, if bamboo wattle and daub wall is used as an envelope, several factors should be considered.

First, the design should meet residential needs of daily life according to local conditions. Second, the daubing material should come from local and available resources. Third, the assembly and arrangement of material should be easy to manage. Fourth, the material should be similar in physical character and appearance to concrete in order to reduce cracks and increase aesthetic appeal.

To develop modern bamboo materials, the cost of bamboo products must be decreased. As examples, production techniques can be improved

and factories could be located in bamboo-producing areas in order to minimize transportation cost and energy consumption.

Practical Application of Bamboo Material

Using knowledge gained in researching the methods of bamboo usage in China, the authors improved the traditional bamboo wattle and daub method and built an experimental dwelling to test whether or not the methods were suitable for Thais. The dwelling was built in Ban Ku Ka Sing, Roi-Et province in 2007 (Figure 16). Traditional bamboo wattle and daub technique was applied in the wall enclosure (Figures 17, 18). The authors improved the daubing components by concentrating on the use of local and natural resources, such as earth, lime, sand, sticky rice porridge, *bong*¹² powder, and plant fiber. The wattle and daub wall was cheaper than walls made of wood or brick. Thermal evaluation of the proposed wall indicated that its indoor temperature was similar to that of wood while indoor relative humidity was low, but the most outstanding characteristics were its economical, ecological, and practicable features. (Warunee and Wang, 2007a : 543-553.)

The experiment leads us to suggest that the techniques of standardization and measuring bamboo wall material are innovative and efficient ways in which bamboo wall and daub can be popularized in rural dwellings. Examples are standardization of daub components, bamboo-woven panels, dwelling patterns, and joints connecting the wooden frame with beams and pillars. Some products, however, need further development.

¹² *Bong* (scientific name: *Persea kurzii* in *Lauraceae species*) is known in different regions by various names, including *pong*, *mong*, *mii*, and *yang bong*. It is found mainly in forests of the northeast and part of the north. The plant grows easily in a high moisture environment. Its wood is good for firewood and for making basic tools for daily usage. Its bark is mixed with sawdust in making incense. In construction the bark or resin of *bong* used to daub lower part of wooden posts to prevent weevils, termites, and ants from climbing up to the house. *Bong* in former times was used as an additive like cement.



Figure 16. Map of Ku Ka Sing



Figure 17. Installation of woven walls in an experimental building



Figure 18. Various phases of experimental dwelling construction: mainframe, covered roof, fixed wall, completed floor

The standardization strategy makes bamboo usage more practical in that it enables Thai farmers to easily build their dwellings themselves by following prescribed methods. It also allows rural dwellings to be developed in a more sustainable and economical manner.

We have emphasized on using bamboo materials as well as local resources in order to attain sustainable development. But the use of such materials should not give the impression of poverty. The use of wattle and daub walls can be combined with modern designs to build village dwellings. Moreover, the construction should also include modern industrial materials that can be recycled and adapted for local life. Only in this way can bamboo

materials be utilized and popularized. Because some modern bamboo materials that we introduced are expensive, not only in China but also in Thailand, they are not popular for farmers. In the future, however, we are optimistic that along with technique improvements and lower costs, modern bamboo materials and products can be widely used.

Conclusion

Throughout history, dwellings gradually change in material and appearance due to changes in resources, economic circumstances, social factors, and the environment. No matter what these changes are, dwellings should maintain their environmental harmony, cultural identity, and energy-saving and environmentally-friendly characteristics. The latter issue has become a worldwide public concern today. Although bamboo materials may meet all of these demands, we have to develop applied techniques of bamboo usage and change attitudes toward bamboo. In these ways, modern design combined with traditional, economical, and ecologically-friendly material might propel the sustainable development of bamboo materials. Through modern design, bamboo dwellings may meet the aesthetic demands of villagers, changing the concept that bamboo material represents “poverty.” We suggest the standardization strategy and techniques of bamboo wall material, such as standardization of daub components of wattle and daub methods, bamboo-woven panels, patterns of dwelling, and joints connecting wooden frames with beams and pillars. Through these measures and methods, bamboo materials will become one of the most important resources for rural Thais’ dwellings.

Modern bamboo materials have been developed in China but are still unpopular because of their high cost. Thus, the intermediate technology from traditional experience should be studied in depth for improvement and adaptation to contemporary living. More valuable experiences would be shared with other countries concerning bamboo usage. In this way, people can

have more alternative choices in using bamboo as an envelope for their dwelling's construction. These efforts should lead to public acceptance and the development of bamboo as an ecological building material in the future.

Picture credits

Figure 13 [Online] Available: www.linanwindow.com/chinabamboo/zdb04.htm
(February 3, 2008)

Figure 14 [Online] Available: <http://bbs.szhome.com> (February 8, 2008)

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