

An Sustainable Scaffolding Alternative - Bamboo Scaffolding

Aiyin Jiang, Ph.D., CPC
University of Cincinnati
Cincinnati, Ohio

The concept of sustainable building incorporates and integrates a variety of strategies during the design and construction of building projects. Using green building materials and products in these stages promotes conservation of dwindling nonrenewable resources internationally. Bamboo as a construction material is popular in Southeast Asia. It is environmentally friendly and a renewable resource. However the application of bamboo in construction sites shocks western visitors even if they are construction professionals. This paper introduces the usage of bamboo in the construction industry in Southeast Asia, especially bamboo scaffolding. It indicates the reasons for bamboo scaffold popularity and introduces the process of bamboo selection, scaffold erection, maintenance, dismantling, and reuse. It also discusses the potentials of expanding bamboo scaffolding usage by mixing bamboo and metal.

Key Words: Sustainable building, Green building material, Bamboo scaffold

Introduction

Building and construction activities consume three billion tons of raw materials each year or forty percent of total global use (Roodman and Lenssen, 1995). Using green building materials and products promotes conservation of dwindling nonrenewable resources internationally. Bamboo, being a fast growing and renewable natural resource, was used for construction extensively by our ancient people. It is still a popular building material in Southeast Asia.

Bamboo is primarily a type of giant grass with woody stems (see Figure 1). The stems are called “shoots” when the plant is young and “culms” when the plant is mature. The plant matures very quickly; new shoots grow to their full height in two to three months. Once the plant has matured, the culm size remains the same for the rest of its life. It is a very flexible plant that sways in the wind, but rarely snaps. This characteristic can be attributed to its hollow stem and nodes. Bamboo used in the construction industry can be either in the form of full culms or splits. It may be used in any one of the following building construction areas:

- Scaffolding
- Foundations
- Framing
- Flooring
- Walls
- Roof
- Trusses

The properties of bamboo such as resilience, shape and strength make it an ideal material for construction purposes, even for scaffolding. Bamboo scaffolding is popular in Southeast Asia area, but rarely used in Northern America. This paper introduces the bamboo scaffolding system advantages, life cycle of bamboo scaffold, scaffold erections and maintenance, and explores the expanding use of mixing bamboo and metal to reinforce strength.

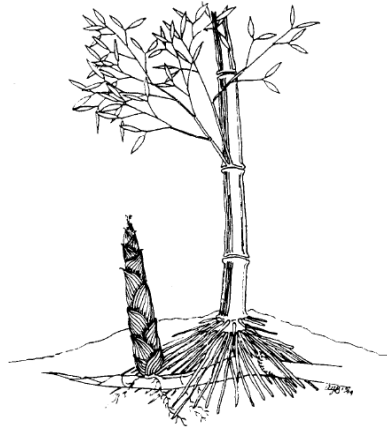


Figure 1: Bamboo

Competitiveness of Bamboo Scaffold

Bamboo scaffolds have been used in building construction in China for thousands of years. Bamboo scaffolds are commonly employed in building construction to provide temporary access and working platforms for construction workers and supervisory staff. Owing to their high adaptability, speediness and low construction cost, bamboo scaffolds can be constructed in any layout to follow various irregular architectural features of a building within a comparatively short period of time. Nowadays, in spite of open competition with many metal scaffolding systems, bamboo scaffolds remain one of the most preferred systems for access in building construction in China and the neighboring areas. The use of bamboo has advantages over other types of scaffolding in its flexibility, cost effectiveness and speediness in construction.

Flexibility

Bamboo can be cut and tailor-made easily to suit any contour of a construction structure. Bamboo scaffolding can also be securely constructed at the middle of a building stretching a few floors. This flexibility of bamboo scaffolding is especially advantageous in heavily populated area where buildings are tall and crowded to provide only limited space for access by scaffolding.

Cost effectiveness

Comparing the price, a typical piece of bamboo is only about 6% the cost of a similar length of steel scaffolding. This vast difference in price is one of the other key reasons why bamboo scaffolding is widely used in China. The following example compares the cost of bamboo scaffold with the cost of steel scaffold in constructing a seven-floor building. (<http://www.tydf.cn/blog/article.php?tid-4309.html>). For a 50m by 10m seven-floor building with a floor height of 3.3m, the parameters for each scaffolding system are as:

- Bamboo scaffold
 - Distance between standards = 0.75m
 - Distance between ledgers = 1.5 m
 - Double row bamboo scaffolding
 - Bamboo scaffold with 6m length = 5 RMB, or 0.83RMB/m
- Steel scaffold:
 - Distance between standards = 1.5m
 - Distance between ledgers = 1.5m
 - Double row steel scaffolding
 - Steel scaffold with 6m length = 112 RMB, or 18.52RMB/m

Table 1
Cost Comparison of Bamboo Scaffolding and Metal Scaffolding

| Scaffold System. | Material | Accessory Material | Transportation | Labor | Waste of Material |
|-------------------------|-----------------------------------|-------------------------------------|--|---|--------------------------|
| Steel | 7,000m × 18.52 RMB/m = 129,640RMB | 3,500set × 5.00RMB /set = 17,500RMB | 140 t × 50 RMB /t= 7,000.00 RMB | 3,500m ² × 5RMB/m ² = 17,500 RMB | 10% × 147,140=14,714 RMB |
| Bamboo | 12,000m × 0.83 RMB/m = 9,960 RMB | 2,500 m × 0.10RMB/ m= 250 RMB | 13t × 60 RMB/t = 780RMB | 3,500m ² × 2.5RMB/m ² = 8,750 RMB | 30% × 10,210 = 1,021 RMB |
| Cost variance | 119,680 RMB | 17,250 RMB | 6,220 RMB | 8,750 RMB | 13,693RMB |
| Total cost variance | 165,593 RMB= \$20,699 | | 165,593RMB ÷ 3,500 m ² = 47.31RMB/ m ² = \$5.91/m ² | | |

Comparing the cost of the two scaffolding systems in Table 1 indicates bamboo scaffolding can save \$20, 699. In other words it may save \$5.91 per square meter in this example. The cost effectiveness of bamboo scaffolding can make its use extremely advantageous.

Speediness

Bamboo is a light-weight material which can easily be manually handled, and the construction of bamboo scaffolding requires no machinery and no sophisticated hand tools. Bamboo scaffolding can thus be constructed much quicker than other types of scaffolding. It is estimated that the erecting of bamboo scaffolding is about six times faster, and the dismantling of bamboo scaffolding about twelve times faster than other types of scaffolding. This speediness of construction is quite often the overwhelming factor in bamboo's continuing use in China and Southeast Asia (Chung and Siu, 1999).

Because of the above advantages of bamboo scaffolding systems over metal scaffolding systems, bamboo scaffolding is continued to be used in the construction of buildings with seven or fewer floors. However, bamboo scaffolding requires special techniques to convert raw bamboo material to useful construction material, and labor training on how to erect the scaffolding is needed also. The following sections describe the life cycle of bamboo scaffold.

The Life Cycle of Bamboo Scaffold

A bamboo shoot will typically take four to five years to mature. The commonly used bamboo types are Kao Jue and Mao Jue. The nominal length of both Kao Jue and Mao Jue is six meters. The external diameter for *Kao Jue* should not be less than 40 mm and should not be less than 75 mm for *Mao Jue*. *Mao Jue* should also have a minimum thickness of 10 mm. Only those bamboos which meet the above criteria could be used for scaffold (Guidelines on the Design and Construction of Bamboo Scaffolds).

Those matured bamboo which meet diameter and strength criteria would be cut and processed for sale. The quality of bamboo is classified into three rates of bamboo: A, B, and C. Rate A bamboo is the best quality with a large diameter and high strength. Bamboos are air-dried in vertical positions under indoor conditions for at least three months before use. Processed bamboos are transported to construction job sites for erection as scaffold. Bamboos on jobsites should be stored in an upright position to make rain drain easily and avoid deterioration. Bamboo scaffold is strictly inspected periodically and maintained systematically till the project completion. It is dismantled after project completion. Dismantled bamboo scaffold is carefully inspected for reusing. Unsatisfactory bamboos are disposed and reusable ones are transported to a new project. Figure 2 shows the lifecycle of bamboo scaffold.

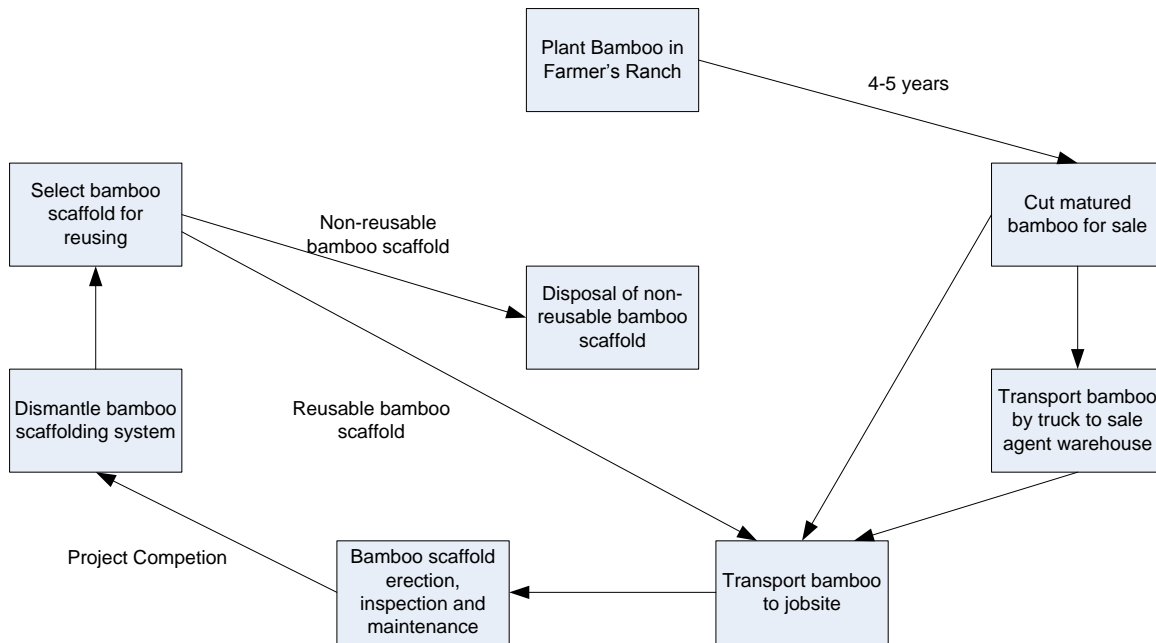


Figure 2: Life Cycle of Bamboo Scaffold

Typical Bamboo Scaffolding Used in the Construction Industry

Typical usage of bamboo scaffolds in building construction includes the following:

- Single-layered Bamboo Scaffolds (SLBS) for light duty work. They are highly adaptable to site conditions with both easy erection and dismantling.
- Double-layered Bamboo Scaffolds (DLBS) with working platform for heavy duty work. They provide safe working platforms for construction activities to be carried out at heights.

Single-row bamboo scaffoldings are constructed nowadays only for the provision of access, whilst double-row scaffoldings, which can provide a secure working platform, are normally used for construction purposes. The bamboo scaffold should be erected, altered, and dismantled by trained workmen under the supervision of a competent person.

Components and Erection of Double Layered Bamboo Scaffold

The double-layered bamboo scaffolding consists of two layers (see Figure 3). The *inner layer* is at about 150 – 300mm from the building face. The *outer layer* is at about 700mm from the inner layer. Working platforms are erected between the inner and outer layers.

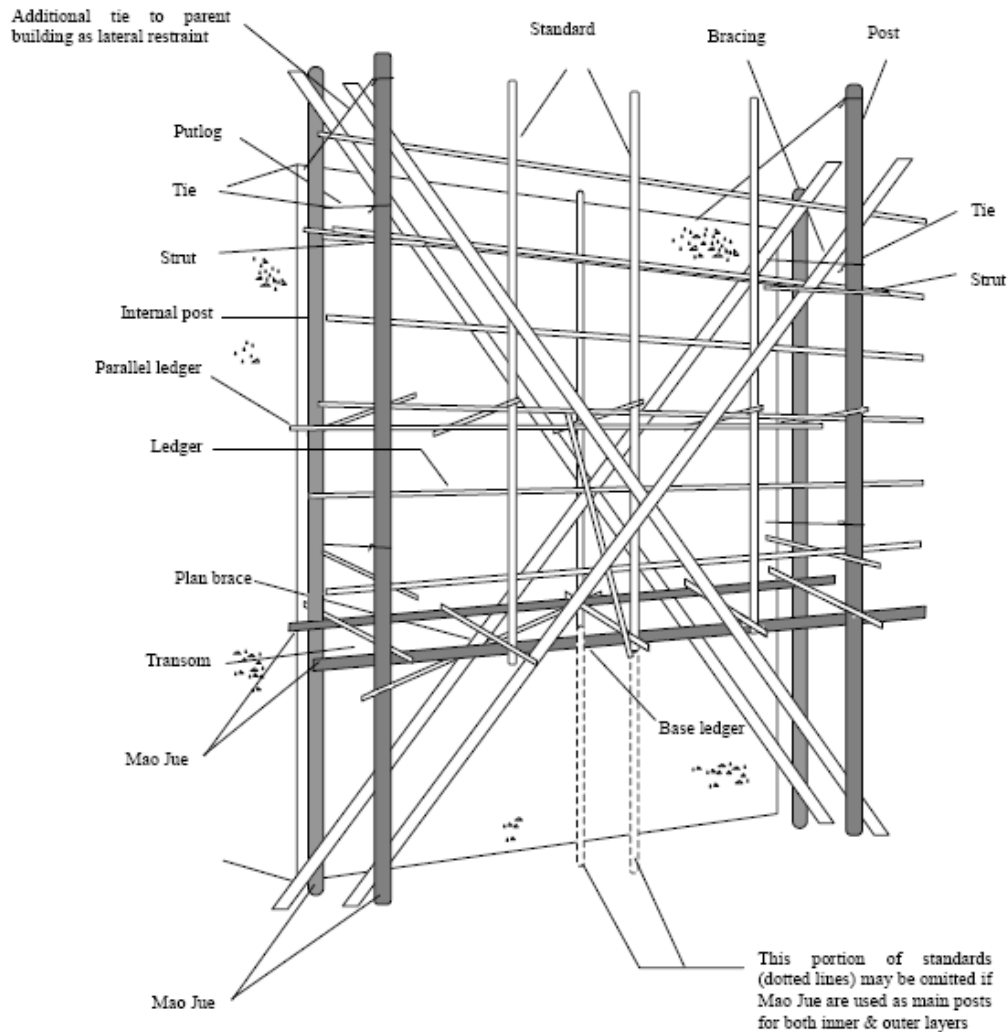


Figure 3: Bamboo Scaffolding System (Sources: Guidelines on the Design and Construction of Bamboo Scaffolds, <http://www.bd.gov.hk/english/documents/code/GDCBS.pdf>)

To start the erection, scaffolders always erect two Mao Jue as the main vertical posts. Posts are the vertical members which rest on the ground or steel brackets and are usually in good quality and strong Mao Jue. They would then be connected with horizontal ledgers in order to fix their position. Then, three Kao Jue will be erected in between the two Mao Jue as standards. Standards are vertical members that overhang on the ledgers and would not rest on ground and brackets. Thus, a total of five bamboo poles now span over a distance of about 3m so that the distance between two adjacent standards is about 750mm. The vertical distance between two ledgers (i.e. distance between an upper ledger and a lower ledger) is also about 750mm (2.5 feet); therefore, the bamboo scaffolding is in square form. The inner layer is erected in the same way.

Transoms. They are erected to connect the inner and the outer layers. These transoms are used to support the working platform.

Bracing. The integrity and lateral stability of bamboo scaffolding structure rely on the provision of bracing. For a large area of bamboo scaffolding, only Mao Jue may be used for bracing. Each bracing section should consist of two pieces of bamboo, which are fixed in an “X” shape and usually in an angle between 60 - 70° over the section of bamboo scaffolding to be braced. Each bracing should also be tied to both the standards and the transoms of the scaffolding. In this way, the loading on the scaffolding can be distributed evenly.

Steel brackets. They are essential to the overall stability of a bamboo scaffold. Figure 4 shows the details of a steel bracket for the support of posts of a bamboo scaffold for construction site. Steel Brackets are in a triangular shape and are used to support and transfer the loading from posts to the facade of a building. Each post should rest on one steel bracket, and the horizontal distance between steel brackets is about 3m. All steel brackets should be securely mounted onto the structural elements of a building with high quality anchor bolts.

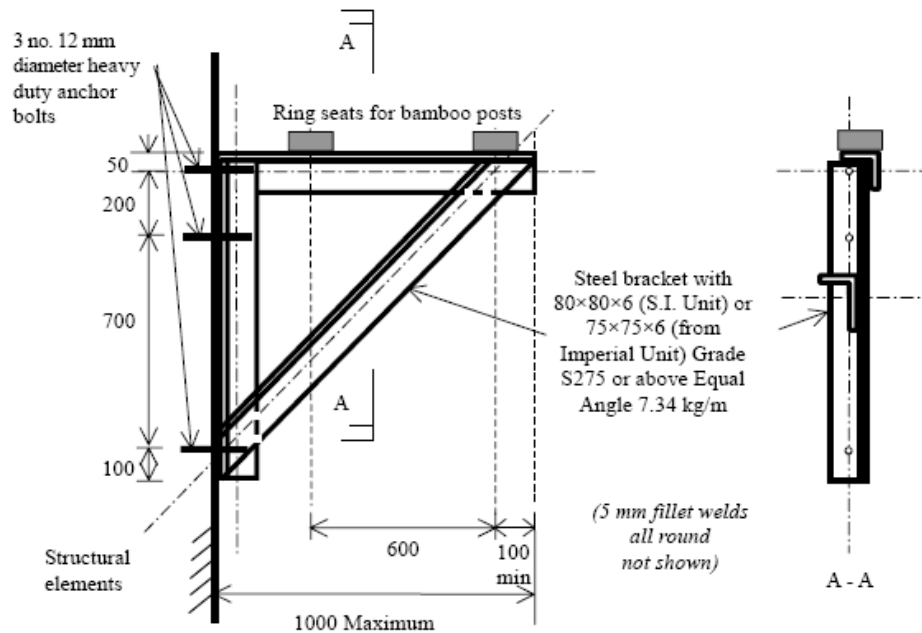


Figure 4: Details of Steel Bracket (Sources: Guidelines on the Design and Construction of Bamboo Scaffolds, <http://www.bd.gov.hk/english/documents/code/GDCBS.pdf>)

Catch fans. These are used to prevent debris falling from height, which may endanger the public. Size and inclination of catch fans are usually determined according to actual site conditions. Figure 5 shows catch fans on construction site. Figure 6 displays the details of catch fans. Catch fans are usually required at five-story intervals or 15m vertical intervals, and they are connected with platforms, which are covered with galvanized zinc sheets in order to have better performance for debris collection and removal. They are often connected to the outer layer of bamboo scaffolding. If a catch fan is too large, additional reinforcement, such as hang pole and raker, are required.



Figure 5: Catch Fan

Working platforms. These are used to provide access for workers and provide a leveled and safe working area for workers to carry out their construction work. Working platforms may be covered by planks and are mainly used by plasterers and painters. A scaffold greater than 15 m in height, should be designed by a design engineer.

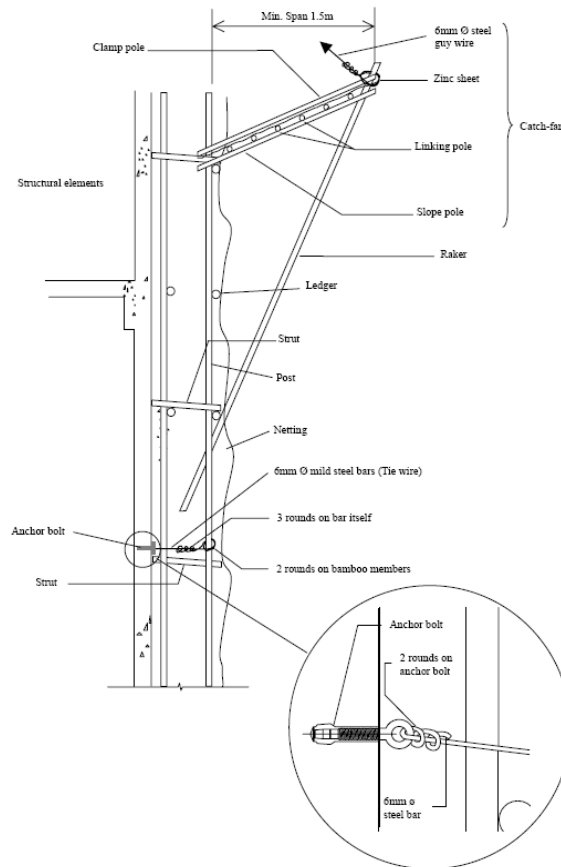


Figure 6: Details of Catch Fan (Sources: Guidelines on the Design and Construction of Bamboo Scaffolds, <http://www.bd.gov.hk/english/documents/code/GDCBS.pdf>)

Maintenance and Inspection

Bamboo is a natural material, and it expands and contracts as the moisture content changes. Proper workmanship, close supervision, and frequent inspection are required to ensure the structural integrity of the bamboo scaffolds after the scaffolding system is erected. A competent person should check the strength and stability of the scaffold and ascertain that there are no defects and deterioration. The bamboo scaffolding works should be supervised by the inspector as follows:

- upon completion of the first erection of the bamboo scaffold;
- at intervals of not more than 14 days after the first inspection;
- after a tropical cyclone, heavy rain or storm;
- after any substantial addition or alteration of the bamboo scaffold; and
- before commencement of dismantling the bamboo scaffold.

The competent person should record the inspection and findings in the inspection record form. Defects found during the inspection should be rectified immediately.

Dismantling

Bamboo scaffolds must be immediately removed once the construction/repair works are completed. Dismantling work must be carried out by trained workmen under the immediate supervision of a competent person.

Before dismantling the critical members, such as ledgers, ties, struts, rakers, transoms or bracings, the stability of the bamboo scaffolds must be assured by fixing a similar piece of bamboo member at a lower level before removing that critical member. Dismantling should start from upper level to lower level, from exterior to interior and from non load-bearing parts to load-bearing parts. No materials or debris shall be stacked on the scaffold.

Although bamboo scaffold has advantages over metal scaffold on flexibility, cost effectiveness, and speediness, there are some factors preventing this system from being used widely. The next section presents these factors.

Factors Regarding the Potential Problems of Bamboo Scaffold

Bamboo scaffold has been chosen as temporary working platform by the majority of building contractors in China and neighboring areas because it is light and easier to fabricate. Consequently the load on supports like steel brackets can be smaller and more economical. The structure of bamboo scaffold relies on the strength and quality of each piece due to the variation in size and its mature lifetime. Even though the checking of stability can be carried out from time to time, the maximum buckling strength may not be assured. In addition, the collapse of bamboo scaffold due to bamboo failure is mostly caused by the degradation of bamboo itself and by strong wind, such as a strong monsoon

or typhoon. Moreover, sustained high moisture level in Southeast Asia, such as in Hong Kong, is the key factor that affects the quality of bamboo significantly, thus shortening the useful life of bamboo pieces.

Intentional destruction by other trades' workers is also very common, especially the plasters and workers from water pipe installation. They usually damage the connection of R6 wires between external wall of building and the double layer bamboo scaffold to facilitate their completion of works. On the other hand, unnecessary and nonprofessional modifications of bamboo scaffold by cutting individual bamboo into pieces to create openings for transferring construction materials by those workers always underestimate both the short-term and long-term effects leading to various extent of structural deformation. Most of the collapse cases of bamboo scaffold involve either part of the above scenario or the combination of all situations due to the above mentioned irresponsible behavior done by other workers during the construction period.

To circumvent the problems of improving strength and elongating the life span of bamboo scaffolding, some efforts may focus on the following:

- Keep training the other crafts to use bamboo scaffold carefully and safely. Construction project managers may develop safety manuals and programs for all trades to use safely bamboo scaffold.
- Incorporate other highly strong structural members into bamboo scaffold system to improve strength and avoid the moisture issue of this system.

Scaffolds with Bamboo and Steel Members

With the advantages of flexibility, efficiency, and cost-effectiveness, bamboo scaffold is still preferred for most of commercial application in Southeast Asia. However, some bamboo structural members may not be able to resist the applied loads because of various reasons. One solution is integrating other highly loaded structural members resting on ground or brackets to improve the strength of the system. They can be made of steel or other metallic elements. At present, the innovative patented scaffolding system is made partly by bamboo (60%) and (40%) of steel (Poon, 2007)

In the design of mixed metal-bamboo scaffold, only metal tubes are used for the structural members. Therefore, any cases of bamboo failure due to self-deterioration would not affect the overall structure. Furthermore, metal tubes are a much stronger materials than bamboo. Modifications or intentional damages by other parties are not easy to achieve. The stability of mixed metal-bamboo scaffolds can be shown by the installation of "L" shape steel bar putlog, which is fixed to the wall by an anchor bolt. Unlike the R6 wire used in bamboo scaffolds, external destruction of mixed metal bamboo scaffolds can be minimized to maintain the good condition of scaffolding at all times.

Recently, a new type of scaffolding mixed with steel tubes and bamboo poles has been used in Hong Kong. This type of scaffold has a similar structure to the traditional bamboo scaffold. It comprises post, standard, ledger, bracing, transom and working platform, etc. The whole structure will be secured by a putlog system. In this steel-bamboo mixed structure, load bearing members of the scaffolds (such as the post, base ledger and bracing) are steel tubes or fiber-reinforced plastic tubes, coupled by metal couplers at intersection points. For those non-load bearing members, Kao Jue bamboo poles will be used. Similar to traditional bamboo scaffolding structures, these Kao Jue bamboo poles are secured by nylon ties at intersections between bamboo members or bamboo-steel members.

This type of mixed structure has both the advantages of bamboo scaffolds and metal scaffolds. Structurally, as the load-bearing members are steel tubes, it will be more durable and not vulnerable to accidental damage by workers. It will also maintain the high flexibility of bamboo scaffolds and can suit most of the irregular architectural features in building construction. The erection and dismantling time of this mixed structure will be much less than that required by metal scaffolding.

However, as this type of scaffold comprises both bamboo and steel elements, the skill requirement for scaffolders will be much higher. Workers should be familiar with both skills in bamboo scaffolding and metal scaffolding erection. Regarding the cost, this type of mixed scaffold will be, to a certain extent, higher than traditional bamboo scaffold as bamboo poles and nylon ties are much cheaper than steel tubes and couplers. Roughly speaking, the cost ratio of bamboo scaffold, bamboo-steel scaffold, and steel scaffold is about 1:3:6 for one construction project (Tong, 2002) But since the maintenance costs for these three types of scaffolds are just in the reverse ratio and the steel tubes can be reused for many times, the cost difference will be leveled out when more and more projects are taken into consideration.

Conclusions

Bamboo is natural and renewable material for building construction. It is environmentally friendly. It can be used as roofing, wall, framing, foundation, flooring, and scaffolding. As material for scaffolding, the system is flexible in providing working platform and access to building in limited construction space. The system is also efficient and cost-effective. It is a popular scaffolding system in Southeast Asia. However, there is a general misconception from Western World that bamboo scaffolding is a very dangerous system and trade. The safety to users of bamboo scaffolding is, of course, a complex issue. It involves total quality control process from erection, inspection, maintenance, dismantling, and appropriate training in using bamboo scaffolding. If bamboo scaffolding is properly maintained and is not willfully or unknowingly damaged by other trades, it should at least be as safe as any other types of scaffolding used on construction sites. To improve the strength of the bamboo scaffold and improve quality of individual element in the system, metal element can be incorporated. This mixed bamboo-metal scaffolding has advantages of both metal scaffolding and bamboo

scaffolding. It prevents intentional or unknowing damage to the scaffolding. It also has the flexibility of bamboo scaffolds in an irregular architectural layout, speediness in erecting scaffolds, and cost-effectiveness in comparing to metal scaffold. With the open competition of other metal scaffold system, bamboo scaffold and mixed bamboo-metal scaffold provide two more options for construction professionals. More research is needed in comparing these scaffolding systems in terms of cost saving, speediness, flexibility, and other concerned issues in order to provide more information for construction professionals to make decision on selecting the right scaffolding system for a project.

References

Appropriateness in using bamboo scaffold for constructing buildings less than seven floors, [WWW document]. URL <http://www.tydf.cn/blog/article.php?tid-4309.html>

Chung, K. F. and Siu, Y. C. (1999), *Erection of Bamboo Scaffolds*, Hong Kong Polytechnic University and International Network for Bamboo and Rattan, Hong Kong, 1999, p. 6.

Guidelines on the design and construction of bamboo scaffolding, <http://www.oshc.org.hk/download/publishings/1/1928/06.pdf>

Guidelines on the design and construction of bamboo scaffolds, <http://www.bd.gov.hk/english/documents/code/GDCBS.pdf>

Poon, C. S. (2007), Metal-bamboo matrix system scaffold, [WWW document], <http://www.cse.polyu.edu.hk/~cecspon/lwbt/Scaffolding/Scaffolding.htm>

P. Van Der Lugt, A.A.J.F. and Janssen, J.J.A. (2006), An environmental, economic and practical assessment of bamboo as a building material for supporting structure, *Construction and building materials*, 20 (9), Nov 2006, 648-656

Roodman, D. M. and Lenssen, N. (1995), *A building revolution: how ecology and health concerns are transforming construction*, Worldwatch Institute, Washington, D.C., March 1995, p. 5.

Tong, A. I. (2002), Bamboo scaffolding – practical application, *Bamboo scaffolds in building construction - an alternative and supplement to metal scaffolds*, *Proceedings of international seminar*, May 11, 2002, Hong Kong