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Public constructions made with bamboo: lessons learnt from the 'Vergiate bamboo pavilion' in Northern Italy

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Abstract—Bamboo-made constructions appear to have a good market potential in developed countries and could involve developing-country-based suppliers of bamboo materials. Bamboo is one of the rare commodities that can be harvested by local people; be handled with low-capital equipment; be fabricated in craft industries; and yet still can be sold in the so-called developed world. Therefore, trade in bamboo products can contribute to poverty alleviation in rural areas of developing countries. Bamboo furniture, parquet or handicrafts have already established a distinct and growing market niche in many countries. The paper considers the use of bamboo materials for building public or private constructions in developed countries such as: garden houses, pergolas, pavilions and carports.

Complex technical and legal requirements are involved when using bamboo poles in buildings. In spite of the versatility of bamboo and the progress made in technology and design for bamboo-made constructions, still a number of technical, legal, trade and marketing-related issues will require further development before a market for bamboo construction products in developed countries can really take-off.

Although the possibilities of using bamboo as a structural material are really amazing, bamboo is still largely ignored by building codes and legislation across many countries. Some constraints and implications for using bamboo as a building material are highlighted in this paper. They are partly based on the construction process of the first permanent bamboo building for public use in Vergiate (Varese, northern Italy), from direct information and contacts, as well as from other experiences.

Key words: Bamboo constructions; building legislation; building standards; bamboo trade; sustainable development.

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INTRODUCTION

The Vergiate bamboo pavilion is a public building entirely made of bamboo, whose design and implementation were commissioned to the Italian non-profit association EMISSIONIZERO by the Municipality of Vergiate (a small village in the wealthy province of Varese) to build a new structure to regenerate an area traditionally destinated to public recreation. It was built from September 2002 to June 2003, under the guidance of Mrs. Valeria Chioetto, founder and Chair of EMISSIONIZERO, and the architect Neri Braulin, director of works and member of the Association. EMISSIONIZERO is part of the international network of bodies who adopt the ZERI Foundation Methodology (www.zeri.org).

The first event organized by EMISSIONIZERO to celebrate this unique achievement took place on 24 May 2003 and consisted of a workshop organized by EMISSIONIZERO on 'Bamboo, properties and uses' by Prof. Liese. The workshop brought together some 30 participants from a number of countries, mainly architects or people directly involved or experienced with (bamboo) constructions. The workshop was a good opportunity to discuss the potential of bamboo, but also to shed light on some constraints associated with the use of bamboo as a construction material. Key findings of the workshop, together with some of the experiences gained by building the pavilion are summarized in this paper.

THE INSPIRATION AND MAIN OBJECTIVES FOR BUILDING WITH BAMBOO

The Vergiate Pavilion is the first permanent construction for public use made of bamboo in Europe. It has been inspired by the ZERI Bamboo Pavilion, which was constructed for the Expo 2000 in Hannover, as a practical and spectacular example of the ZERI principles [1]. The Zero Emissions Research and Initiatives (ZERI) Foundation develops strategies for a more sustainable use of natural resources, in order to satisfy the basic needs of all people while causing no harm to the environment. ZERI focuses its attention on the promotion of an environmentally-friendly and equitable development, and promotes the use of bamboo as an ecological material for buildings (more information can be found at: http://www.zeri.org/projects/growyourownhouse.htm).

The environmental reasons for encouraging a more intensive and geographically enlarged use of bamboo are related to its fast growth and therefore to its high rate of fixation of CO_2.

KEY BENEFITS AND CONSTRAINTS OF BAMBOO AS A BUILDING MATERIAL IDENTIFIED FROM THE VERGIATE CONSTRUCTION

The Vergiate Pavilion [2] was built as a municipal recreation area. It covers an area of 480 m^2 (32×16 m) and is composed of three bodies with different heights: the

Figure 1. Side view of the building.

central one is almost 7 m high at the ridge while the two at its sides are 1 m lower (Figs 1 and 2).

The distance between the pillars in the cross section is 10 m. The structure is made by 15 trusses at a modular distance of 2 m sustained by three pillars, one vertical and two as buttress. It is a building open on 4 sides, with no walls apart from the pillars. The roof is made of Canadian tiles fixed on a timber layer (Fig. 3).

The technological process was a semi-prefabricated one: the trusses were made on the ground and then lifted on scaffoldings in the right position and height, and then joined together at the ridge and at the main beams. Only after that, the pre-cut pillars with their appropriate fish mouths were fixed to the trusses and finally the foundations in concrete were made (Fig. 4). The technique used for the joints was the same used by the Colombian architect Simon Velez for the ZERI pavilion: threaded bars and concrete inside the joints (Fig. 5). The ZERI Pavilion had a diameter of 40 m and a height up to 14 m.

The construction started in Vergiate in September 2002, with 400 *Guadua* bamboo poles imported from Colombia. Still in Colombia, they had been treated in a smoke-chamber: a preservation technique originally used in Japan and recently initiated also in Colombia.

The pavilion is surrounded by trees and has a nice and ‘exotic’ look (Fig. 6). The visual aspect of bamboo constructions has in general a high appeal to people, particularly in ‘cool-climate’ developed countries. This may be of particular interest; for example, for marketing purposes at commercial fairs, since bamboo-

Figure 2. Front view of the building.

Figure 3. Detail of the roof.

Figure 4. The foundation.

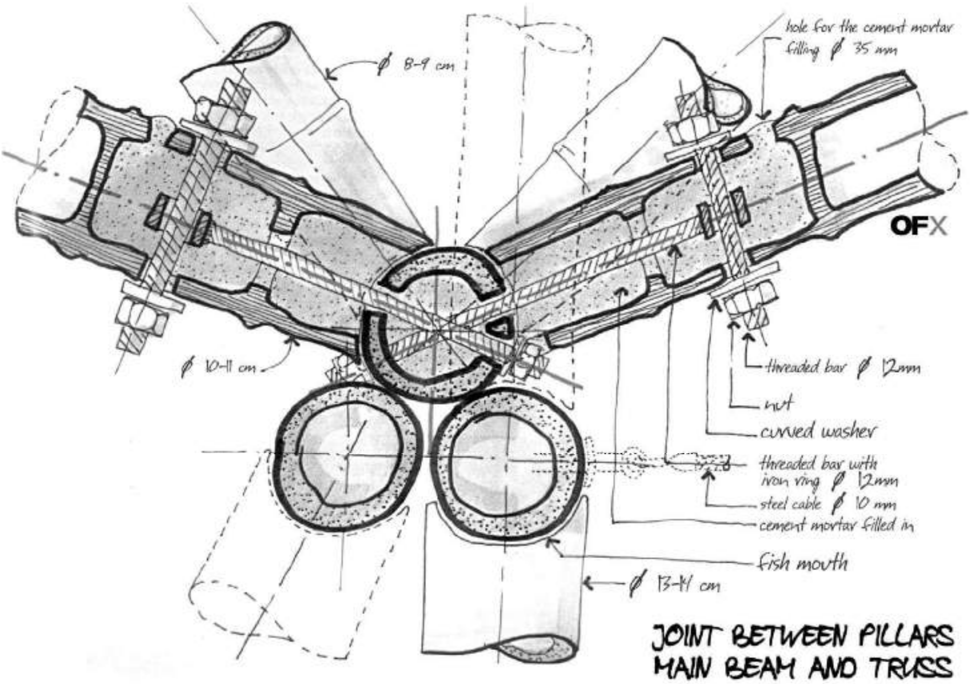

Figure 5. Drawing of the joint between pillars, main beam and truss. The right to reprint this drawing is kindly acknowledged. Reprinted from Ref. [2].

Figure 6. The building in its green environment.

made constructions may attract more 'visitors' then those made out of steel or even timber (another very recent example of bamboo construction in Europe, which is intended to be a permanent structure as well, is the 40 m^2 pavilion built at the International Garden Exhibition, Rostock 2003, Germany, by the People's Republic of China).

Cost

The cost of materials and tools needed for the construction of the Vergiate Pavilion, being an open, wall-free structure, was €95 per m^2 (labour costs excluded). Considering that the same structure built in timber would require the use of laminated wood, due to the large cross-section (18 m), we can state that a bamboo construction is remarkably cheaper than an equivalent one in timber.

What does represent a constraint, at least for the time being, are the costs related to manpower. In the Vergiate building process, mainly non-professional workers were employed, as the initiative was intended as a series of 'learning by doing' training workshops. Nevertheless, more than 3/4 of the people who collaborated to build the pavilion were paid by the hour on a basic standard wage for non-professional temporary workers in Italy. Any generalization whatsoever regarding the relevance of labour in a bamboo building process is, therefore, inappropriate if based just on the Vergiate case.

It is important to note, however, that the use of bamboo from harvesting through preservation and to the actual building, is a very labour intensive process. In our industrialized countries and in particular in Italy, in constructions using materials other than bamboo, such as timber, concrete, brick, steel, etc., the percentage of manpower costs can reach 45–50% on the total costs.

In the Colombian area where bamboo constructions competences and skills are mostly developed nowadays, for an average size and complexity bamboo construction, manpower costs are approximately 35% of the total cost, in which are included the hours needed for the cutting, the preservation treatment and related transportation, on top of the actual building hours. It remains to be seen whether in a medium term future the so called developed countries will be able to learn how to build with bamboo so well as to become competitive with the specialized Colombians ovreros of the Zona Cafetera. At least at the moment bamboo building manpower is out of doubt much more convenient in Colombia than in Europe. Both in strictly economical terms and of course in social policies, the import of processed bamboo construction components and systems implying work and, therefore, with value added to the simple import of bamboo poles, can indeed contribute to prevent local and global environmental and social calamities.

Even with the acquisition costs involved in buying them, treated bamboo poles still maintain bamboo construction quite competitive if compared to timber, steel, stone or concrete for buildings of similar structural performances. Nevertheless, the costs involved in using bamboo as a building material should not be underestimated by any potential contractor.

Technological constraints

Bamboo is a versatile material for constructions. Technology and design for bamboo-based constructions have made considerable progress, resulting in impressive designs in Latin America and in the Far East [3–6]. However, there are some key issues and constraints that have to be considered when promoting bamboo as a construction material for global markets.

Quality of the material

Only bamboo culms older than three-four years should be harvested for constructive uses since during 'maturation' the culms become stronger. Only by experience, it is possible to distinguish visually 'good' culms from 'too young or too old' ones and, therefore, in some countries it is common to mark the years on the growing culm till it is mature for harvest.

The mixing of immature culms within an assignment of culms for sale, particularly when dealing with large volumes for industry or for overseas buyers, may create serious difficulties to the end user. Immature culms also tend to split easier. For large industrial deliveries of culms, a chain of custody on the quality criteria of the culms will be needed.

Protection and preservation

Culms are easily biodegradable and, therefore, need protection and treatment against insect/fungi even more than timber [7]. The technologies of applying bamboo treatments are different in view of the peculiar anatomical composition of bamboo culms. While timber is a more or less homogenous porous material, bamboo is water-tight on the outside of the culm and hollow in the middle. This pipe-like structure is intersected by walls (internodes). As much as possible non-chemical protection should be applied, to avoid danger to mammals and environmental damages. One of the most important measures is to keep the culm protected from access of moisture. By doing so, degradation by fungi can be prevented. Protection by appropriate construction design is an important initial step in any building project. As a non-chemical preservation system, the smoking method is being applied. However, the exact technical parameters have still to be certified.

In certain cases the use of chemicals for preservation has to be applied. There are several technologies for chemical preservation. One of the technologies (for fresh un-split culms) is the sap-replacement method, by which the sap is pushed out by the preservative, leading to a clean surface of the culm and a complete inner protection.

Another method aims to get the preservation liquid from the inside of the culm into its wall, towards the outside. Therefore, holes have to be drilled in each internodal section of the culm in order to allow the entrance of the chemicals.

Bamboo culms tend to split and there is no method to avoid this natural property. When a crack happens, the inner part of the culm becomes exposed to possible fungi/insects attacks, if not properly treated previously. Outdoor exposed poles will also show weathering effects (like changes of colour or the coming out of spots) that might be unpleasant and against which a finish maybe applied.

Form of the material

As mentioned above, bamboo culms look from the outside just like iron-pipes. However, while those have standard and constant sizes for their diameter, thickness, length and are straight, bamboo poles come as nature has created them with no 'standard' sizes at all and they are often NOT straight. It is not an easy job to construct a straight building with curved and irregularly shaped poles. For artisan construction, where the builder can select and cut length to size of the right pole for (or bend it to fit to) the right place at the spot during the building process, these 'irregularities' are still well within manageable proportions. Industrial construction, however, generally applies pre-sawn/pre-drilled standard sized poles for modular shapes to be mounted. Due to its non-regular sizes, bamboo production in series can therefore be not easy and surely slower.

In order to accommodate to bamboo, research in technology and design has already advanced much: bamboo sawn lath and lath boards are quite useful for constructions and there is a growing market demand. Further research in technology and in design is needed as the process is still too complicated to be applied easily and economically by construction workers or end-users/buyers.

LEGAL CONSTRAINTS

Legislation applicable to construction materials against bio-degradation and fire, and recycling

Any construction in industrial countries has to comply with existing regulations regarding structural stability and safety measures, including protection against biodegradation, fire, wind, earthquakes and snow resistance. This legislation varies from country to country and is in general more demanding when referring to public buildings. A range of standard norms and tests (virtual and real) exists for buildings made of steel, concrete or timber, in order to verify their structural resistance and the required protection levels against fire, wind or snow.

For bamboo constructions, those testing protocols and models are not yet definitely stated. Structural stability tests are done on a case by case basis. This not only increases the costs of the legal verification/testing process and procedures of the construction, but — more importantly — it leads architects, building constructors or municipalities to select traditional and well-known building materials like steel, concrete or wood instead of the lesser known bamboo. An international building code for bamboo structural design is under discussion by the ISO/TC 165 Committee based on the work of Dr. J. Janssen [6].

Figure 7. Test loading.

In order to obtain the technical permission from the competent German public authority to construct the bamboo pavilion in Hannover, ZERI had to request a 'special admission for an individual case', since in Germany only materials like steel, concrete, wood or stone are submitted to building codes as structural building materials. To get the approval for the construction of the ZERI Pavilion at the EXPO 2000 in Hannover, an impressive range of tests was required and carried out on the real size prototype of the same pavilion previously built in Colombia.

The static test inspection on the Vergiate Pavilion took place on 8 July 2003 (Fig. 7). The structure was loaded with 1400 kg to simulate a heavy snowfall, and with up to 500 kg horizontally to simulate the power of the wind. The deformations caused by the loads were measured.

The loading tests programme was provided by the Studio De Miranda Associati (www.demiranda.it Milano, Italia) while the tests on bamboo specimen to determine the physical and mechanical properties were carried out by the Istituto Masini (www.istitutomasini.it Rho, Italy). The structure was tested by identifing, amongst the 15 trusses built, the one presenting the highest number of irregularities, such as dimensions of bamboo elements, deviations from the straight axis and differences in internodal lengths, wall thickness, etc., hanging the loads on its ridge and measuring the deformations of that particular truss and on the two adjacent ones. During the loading tests, all the three trusses revealed progressive linear deformations, in line with the increase of the weight. The structure was, therefore, certified as adequate to support the loads stated by the security technical norms.

A particular challenge for bamboo made constructions is to adhere to the laws on fire protection of (public) buildings. While steel and concrete beams can be easily protected with fire retardant panels, and timber beams by increasing their cross-section, protection of bamboo against fire is still a technological challenge. In public constructions, this constraint can be off-set by adjusting the design accordingly.

Bamboo biodegradability and recycling norms

An issue of increasing importance relates to legislation regarding the recycling potential of the building materials used. Bamboo, as any other natural material, is obviously fully ecological and, as such, 100% biodegradable and does not require any particular recycling process. What can cause problems are the additional materials and the chemical treatments used in the building process from the cradle to the grave. In the case of the Vergiate Pavilion as it was in the ZERI Pavilion building process, the structural performances were reached by a junction technique implying the use of concrete and iron threaded bars. However, the amount of these materials is confined in the joints and, therefore, much lower than in usual modern hi-tech buildings. The ZERI Pavilion was dismantled after the EXPO 2000 according to the contract with the organizers of the EXPO and the bamboo used was not recycled because of the steel inserted into the poles and the cement injected in the joints. According to the severity of the recycling and/or waste-disposal norms, the recycling of used bamboo poles can be very costly when the construction is to be dismantled, as was the case with the ZERI Pavilion in Germany and this is not due to the quantity of cement and steel inserted but to the difficult selection to be done in order to recover the reusable bamboo poles.

CONCLUSIONS

Bamboo is a beautiful, resistant, flexible and versatile material that can be produced in an environmentally-friendly, renewable and sustainable manner. There is no doubt on the many benefits that bamboo and bamboo products can provide. Its fast growth, easiness of cultivation, harvesting, transport and storage, its impressive strength properties, flexibility and easy handling, make bamboo a most versatile material applicable for a wide range of uses. In addition, the 'look' of bamboo-made constructions has a world-wide market appeal. This may lead to more trade in bamboo products with the involvement of a lot of developing country based suppliers. Bamboo is one of the rare commodities that can be harvested by local people, be handled with low-capital equipment, be fabricated in craft industries, and yet can be sold in the developed world. Increasing trade in bamboo products can therefore contribute to poverty alleviation in rural areas of the developing countries. Moreover, bamboo furniture, parquet and handicrafts have already established a distinct and still growing market niche in many countries.

However, if bamboo poles are to be promoted as a global building material like steel, marble or timber, then building codes and legislation across many countries will need to be reviewed to incorporate regulations and technical norms for bamboo. The intention of this paper is a call to researchers, architects, development agencies and building associations for the promotion of the use of bamboo in constructions world-wide.

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