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Industrialization of round-pole bamboo: Feasible prefabrication and mechanization

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Abstract

Throughout some of the most representative projects carried out at the studio *'bambusa espinosa'* (based in Madrid, Spain), research by practice on composition rules regarding architectural and structural design has been analysed, all strictly related to the making of every project. This research allows to learn about the feasibility of a variety of construction and structural systems through study cases of the own practice developed in countries of 3 continents. These systems have different levels of prefabrication and mechanization, as a result of the functional requirements and the conceptual design of each assignment. The summit project of the research so far is an alternative to only develop projects at the studio: to design and manufacture ready made products, adding value to bamboo where it comes from, not only treating it, but also making prefabricated elements that are easy to assemble as well as to detach. The first product in this work line has been a structural system based on self-standing trusses arranged in groups of 4 to create a pergola, covered by a tension fabric (www.bamboopod.eu).

Keywords: Bamboo, prefabrication, structures.

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1. Introduction

This paper presents an analysis of the most representative projects at the studio of architecture and urban design *'bambusa espinosa'* (www.bambusaespinosa.com) founded by the author and based in Madrid, Spain. The selected projects are taken as study cases of research by practice in the field of architectural and structural design using round-pole bamboos. All the following projects have their design concept intimately related to the construction and structural systems implemented in every case, therefore becoming a primary part in the making of the project. Given the fact that the sites are located in countries of 3 continents (Africa, America and Europe), this analysis invites to reflect about the transferability of well-developed methods from one country to another. The requirements of program, together with the resources available and the time-span of each project, leads to a different approach from the technological point of view, which ends up in a design concept that later on shall be materialized in the building. The level of complexity in the overall system and in the joints are based primarily in the concept of prefabrication, implemented at different scales and resulting in designing, for instance, iron fittings, or any other complement to bamboo, in order to make the system work efficiently. The content of the paper is structured in 3 chapters responding to the dimensions of the modules in the projects: bidimensional or planar modules, three-dimensional or spatial modules, and unidimensional or linear modules.

2. Bidimensional or planar modules

2.1. Self-sustainable boutique lodge (Tanzania)

The requirements of the program shifted from a second house in the first place, to a guesthouse, and finally to a boutique lodge. The site is plot on the foothills of Mount Meru, facing Kilimanjaro and with a panoramic view of the Masai steppe. The whole development had to be self-sufficient at every phase because of the lack of services in the area. The project is based on three strategies, dealing with energy, water and materials. Regarding the latter, bamboo and interlocking stabilized soil blocks were used instead of timber and cement blocks, which are the most common building materials in the region. Bamboo was used for the main structure of the buildings open to public: bungalows and common area. This main structure supports the roof and consists on six triangulated, flat modules composed by beam, column and struts. These six modules are arranged radially, generating a dome with hexagonal base, joint at the peak as a reciprocal structure (Fig. 1).

Fig. 1. Hexagonal dome obtained by planar modules arranged radially as reciprocal structure.

There was no bamboo for construction in the Tanzanian market at that time, so the whole industrial process related to harvest and treat it to get a high-quality building material was implemented at the building site. There were training sessions for local craftsmen to learn about building with bamboo.

2.2. Hotel extensión in Palenque (Mexico)

The client requested the extension of the main building within a hotel compound located along the road to the Mayan site of Palenque (Chiapas, Mexico). In this case there was already treated material available in the area and experienced craftsmen in building with bamboo. A galklery running in parallel to the existing building was proposed, created by seven planar modules. Each one of them was conceived as a truss whose beam was prolonged, generating an overhang (Fig. 2).

Fig. 2. Planar modules in parallel creating a gallery.

3. Three-dimensional or spatial modules

3.1. Tensegrity structure in Majorca (Spain)

A tensegrity-type structure was designed, calculated and built as requested by a circus company to be perform a show on it. Its final height was 8 meters, reached by using 9 bamboo poles compressed by steel cables (Fig. 3). The bamboo poles were assembled previously in

groups of three, each group generating two tetrahedron linked by a vertex. These groups were put together horizontally, on the ground using the steel cables. Later on, the whole, as it was already a stiff structural unity on itself, was lifted up and placed vertically on its final location.

3.2. Experimental greenhouse in Madrid (Spain)

The practical part of the 3-day workshop that took place at the Polytechnical University of Madrid on October 2019 aimed to execute a greenhouse at the agronomical experimental fields in the campus. The design concept is based on structural modules which are three-dimensional and self-standing by themselves. Three of these modules were arranged together and covered with polycarbonate panels previously attached to additional bamboo planar modules on the ground (Fig. 4).

Fig. 3. Spatial modules conforming a 8-meter-high tensegrity tower.

Fig. 4. Greenhouse, result of a 3-day-workshop at the Polytechnical University of Madrid.

4. Unidimensional or Linear Modules

4.1. Prefabricated detachable structures (anywhere)

Aiming for a design which allows to be assembled and dismantled easily, '*bamboopod'* was conceived (www.bamboopod.eu). Finally, the system to manufacture this kind of construction has been fully developed and patented. The main reasons behind the application of this design concept are to reduce the impact of logistics in the sales costs of a bamboo structures, optimize resources (thanks to the controlled working environment at the production plant), and increase precision, what reflects on the quality of the final products (Fig.5).

Fig. 5. Modular prefabricated bamboo structure based in linear elements with PVC covering.

This technology focuses on placing bamboo in the mainstream as building material. The strategy to do so consists on developing products where bamboo plays a crucial role, combined selectively with other materials and adapting it to work together with construction systems available in the market. Used as round poles, not as boards or slats, bamboo is a material which may have even positive environmental impact given its high carbon sequestration rate and the low energy consumption in processing it. Added value driven design, prefabrication, serial production, zero waste manufacturing, ecological surplus and quality working environment are all existing concepts. However, to put them all together harmoniously related to building with bamboo, means an approach not seen up to date. Primary material in the system is bamboo, but it is combined with iron fittings, PVC fabric and, and eventually aluminium based enclosure systems, such as wind blockers or curtain walls. This way, all materials used in the system are either biodegradable (bamboo), reusable (iron) or recyclable (PVC and aluminium) and therefore zero waste manufacturing achieved. Only what it is going to be built arrive at the building site, where no more than 2 persons with wrenches and ladders are required to build a given structure. Dismantled, it is packed in a compact way; i.e., a 7x7-meter module, reaching 4 meters at the highest point, and its covering, takes only 3x1x1-meter. Thus, transport costs are reduced, both in monetary and environmental terms.

The system is conceived to be easily assembled and dismantled with requirements as low as the specified above, this makes it suitable for permanent as well as temporary use. The heaviest component in the system weights 20 kg, to be handled by 1 person. All the components are packed in boxes below 50 kg, to be carried by 2 persons. Electric tools are only used at the production plant, increasing safety. Design principles are not a novelty (prefabrication, serial production and quality working environment among others) but to put them in practice regarding bamboo industry is: Bamboo artisans shift to valued professionals through the implementation of these principles. Combining bamboo structures with tension

fabric as covering and aluminium frames-based systems as enclosures, business opportunities are also created for industry agents at final destinations, due to the competitive advantages the system may provide (Figure 6).

Fig.6. Combination of 2 modular structures based in linear components.

Conclusion

Using bamboo in its natural form as structural material shall contribute to invert the current ecological footprint of the building industry, even in countries which are non-producers. Bamboos are paramount carbon sinks, as timber, but much more renewable. When treated with environmentally friendly methods, bamboo does not stand direct rain and sun, this is the reason why all these structures are self-protected by design, all but the tensegrity in Majorca, which was meant to remain on site for only 3 months.

Bamboos are fast-growing plants working as remarkable carbon sinks while alive, specially before the 5^{th} year after sprouted: during growing and maturing stages, removes $C0_2$ at higher rates than the rest of their lives. Managing bamboo forest and plantations to take advantage of it as building material means storing carbon dioxide from the atmosphere (until that bamboo is burnt or decomposed) at the same time that it is obtained a potentially high-quality building material which might be comparable in structural performance to steel and reinforced concrete. Therefore, global warming is tackled simultaneously in 2 ways: stopping carbon emissions related to building with steel and concrete because there is a reliable alternative, and reducing carbon from the atmosphere by sequestering it.

Conflict of Interest

The authors declare there is no conflict of interest.

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