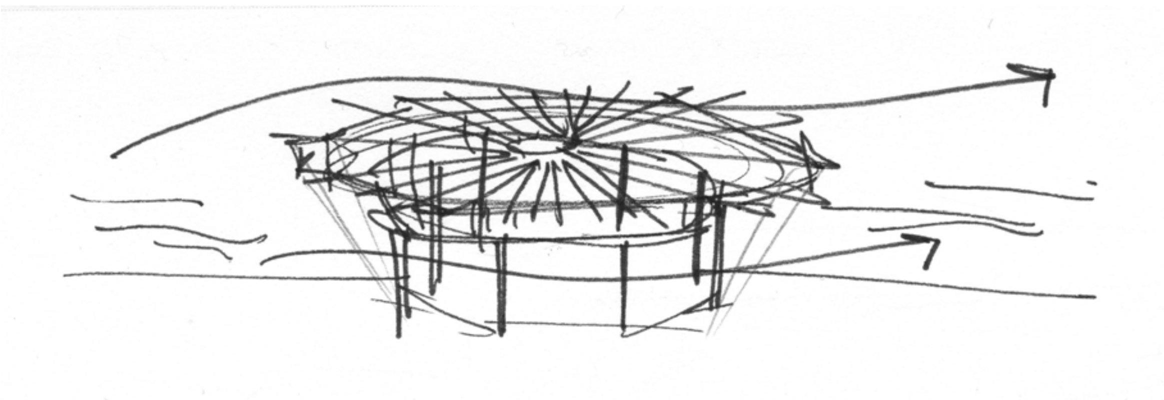
Arch 384 Competitions Elective Fall 2006

Research Essay

International Bamboo Building Design Competition



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Research Essay: Bamboo as a Building Material

Bamboo always plays a key role in the daily lives of people around the world, especially in Asia, Latin America, and Africa. Besides being an aesthetic landscape feature, it is a sustainable material for designing furniture and crafting material. More importantly, it is truly an economical natural building material. Statistically, its ratio of strength to weight is better than graphite, it is also the fastest growing plant on earth (Goldberg, 10). On average, the bamboo culm only requires a single season of growing time, about six weeks to reach maturity, and acquires its ultimate structural strength within two to three years. This fast-growing and self-renewing quality of bamboo has been recognized and admired in a society that concerns with sustainability. In comparison to wood, concrete, and steel, bamboo require minimal mount of manufacturing energy. In terms of sustainability, the speed of a material's regeneration should match the need for its utilization. Bamboo is the only existing construction material has this quality.

Figure 1 Bamboo Species (Kries 158)

Technically, bamboo is classified as a grass. Its size and height varies greatly depending on the species and the growing conditions. Some species stay low to the ground reaching only 6 to 12 inches high. Other giant grasses soar up to a height of more than a hundred feet (Goldberg, 14). In comparison to other species, the Guadua genus is most commonly used as structural elements. It distinguishes from other bamboos with their long, thick, and thorny culms. Its hollow core reduces the self-weight of the bamboo structure, but does not affect its strength. Its long and straight fibers make it very resistant to the stresses of traction and compression.

Figure 2 Guadua Bamboo (Villegas, 24)

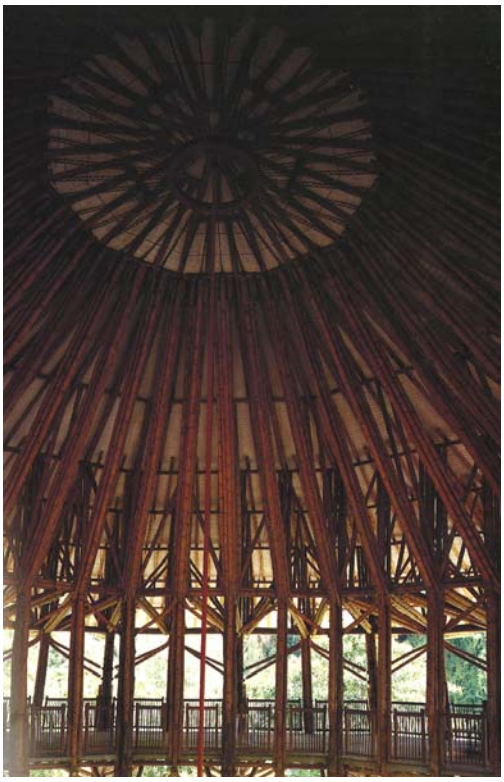

Figure 3 Guadua Pavilion (Villegas, 53)

The Guadua Pavilion in Colombia, built by Marcelo Villegas is intended to showcase the structural strength of the Guadua species. It has the geometric shape of a ten-sided polygon. Its roof is constructed using guadua bamboos, which is topped by a cement mortar for waterproofing. This topping greatly increases the self-weight of the roof, which has a dead load of 200 kg per square meters. There are forty structural supports; each comprises a bunch of six guadua pieces, tied together with steel clamps.

Another good example of using guadua bamboo is the cultural center named as “Island Village” dedicated to Jamaican Music, built Ann Hodges and Simon Velez. Its octagonal roof is supported by four groups of columns, each made up of three posts of pine wood. The roof structure is entirely made of guadua bamboo joined to the wood columns. Traction ring, stainless steel rods, and bronze connections are used in combination with bamboo, which made up the structural system. These metal connections are joined to the guaduas by means of having cement mortar injected into their hollow cores. The significance of this pavilion is that it is “the first guadua structure built in the Caribbean and may mark the start of a culture of guadua-use in Jamaica, where bamboo is found throughout the island” (Villegas, 120).

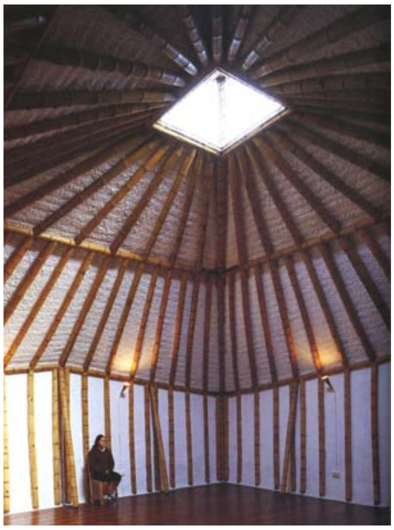

Figure 4 Island Village (Villegas, 120) Figure 5 Libre Bogotá (Villegas, 98)

According to the specific characters of bamboo, it has certain limitations in large scale buildings. As a result, it is more commonly used in smaller typologies, such as houses, bridges, pavilions, and garden structures. In spite of this limitation, it is probably the only natural building material, which has both compressive strength and tensile flexibility. According to structural tests, it has greater strength than steel in tension; while it is stronger than concrete in compression. "The human form and spirit would have much to emulate in the power of bamboo: standing upright, yet strong and supple; being flexible yet resilient in light of nature's forces; being grounded with an extensive rootedness to the earth yet light and airy in response to the slightest breeze" (Goldberg, 12).

Figure 6 Garden Structure (Goldberg, 147) Figure 7 Bamboo Bridge (Villegas, 23)

Architecturally, when using bamboo as structural supports, giant bamboo timbers are bolted together in triangulated trusses, which are strong enough to span freely 6 to 8 meters while supporting heavy live loads and dead loads above. Another interesting way of using bamboo as structural elements is by bundling up flattened bamboo culms with their nodes removed. In addition, crushed bamboo pieces can be laminated into bamboo glulams with the capacity for longer span. Thinner bamboos can be fabricated as materials for exterior, floor, and ceiling finishes.

Figure 8 Bamboo Structure of C.I.R.E.C.A.

(Kries, 132)

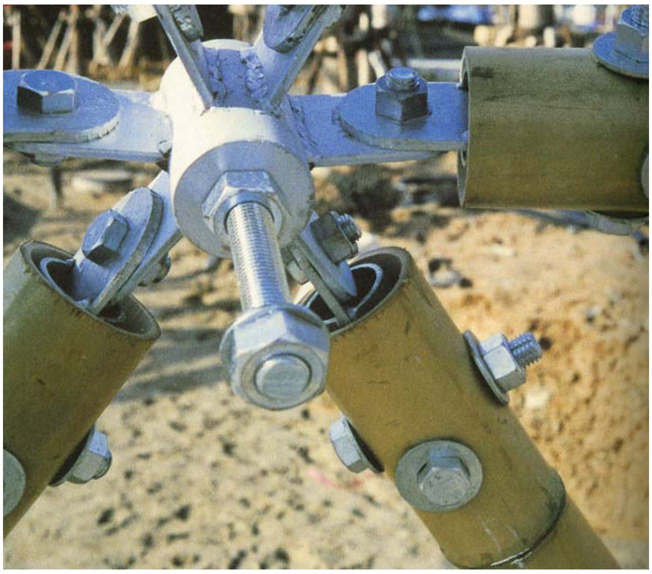

Figure 9 Bamboo Connection

(Kries, 108)

Figure 10 Experiments for Connecting Bamboo. Renzo Piano

(Kries. 116)

There are infinite solutions to use bamboo as structural material. For instance, hyperbolic shapes formed by a bamboo mesh could be another creative design. The Mexican Roof of El Centro Comunitario is one of the great examples of using flattened bamboo for its structural roof mesh. “The complex process of development inevitably led to the creation of The Roof, a functional sculpture that serves as protection from the hot sun and to collect water in the rainy season, as well as differentiating the shaded space” (Prix, 5).

Figure 11 The Mexican Roof Night View (Prix, 77)

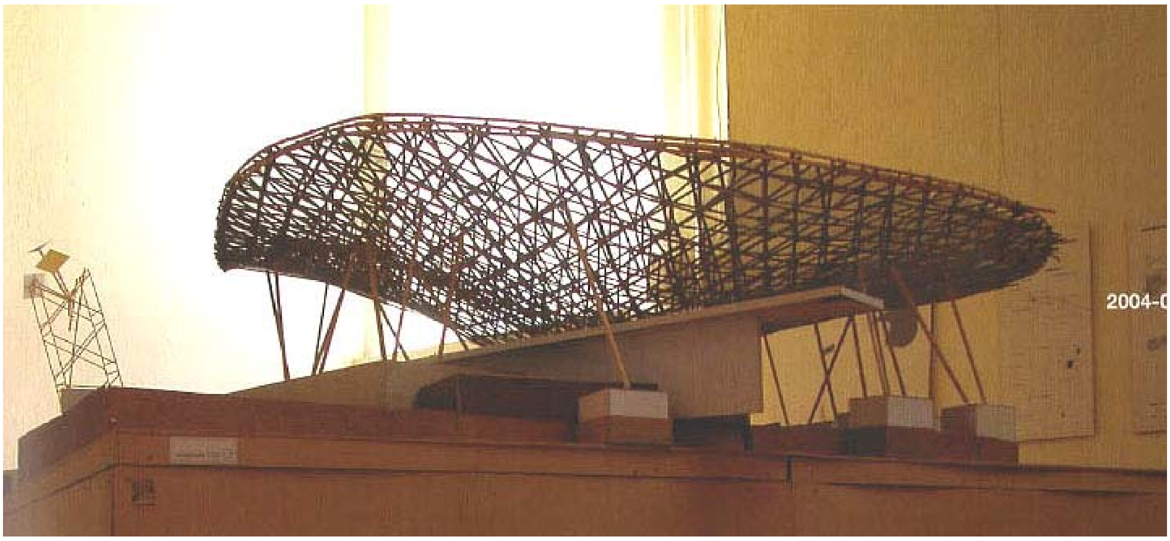

Figure 12 The Mexican Roof Model (Prix, 51)

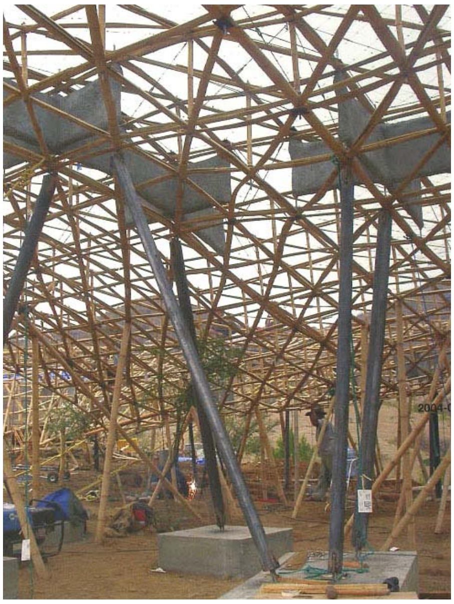

Figure 13 The Mexican Roof - Flattened Bamboo Structure (Prix, 59)

Culturally, in many countries, bamboo has been related to spiritual and ritual activities for centuries. Especially in Asia, this ideology is deeply rooted in its culture. "While the Chinese use bamboo in engineered structures, the Japanese favour the beauty of bamboo in ornamentation and decoration, as well as for use in ritual ceremonies" (Goldberg, 13). For instance, a teahouse would be constructed mostly of bamboo as a sacred space in Japan. Despite of the short durability

Figure 14 Japanese Style Pavilion (Goldberg, 122)

of bamboo if left untreated and unprotected, these ritual buildings are very well treated and protected cautiously, so that the material can be serviceable for fifty, even a hundred years (Goldberg, 42). Some Chinese temples, Japanese homes, and ceremonial teahouses last for more than a century. These cultural associations have inspired the architects for the Pavilion for the Festival of Vision, exhibited in both Hong Kong and Berlin. This temporary outdoor performance venue highlights the elegant craft of jointing, where no bamboo members are perpendicular to others horizontally and vertically as in traditional bamboo construction. This is a contemporary concept of using bamboo instead of the classical linear bamboo structures, where “the bamboo simultaneously fulfills the functions of exterior enclosure and interior backdrop, forming a sturdy and stable structure, whilst affording visual depth” (Gutierrez, 25).

Figure 15 Festival of Vision Pavilion (Gutierrez, 29)

Figure 16 Festival of Vision Pavilion (Gutierrez, 31)

Simon Velez has been known as the “pope for bamboo architecture” (Oprins, 104). “His impressive engineering achievements are manifested in generously overhanging roofs, ingenious load-bearing structures, sophisticated joints, and an innovative combination of materials” (Kries, 9). The largest construction in bamboo today is the pavilion of the Swiss environmental foundation ZERI made for the World Exposition in 2000, designed by the bamboo construction master. Its roof bridges a 40 meters span, a space based on a 10-sided polygon, with a peripheral overhang of 7 meters wide, supported 14 meters above ground by only 20 bamboo columns. This project has been regarded as “an architectural masterpiece, combining building intelligence, elegance, harmony, and economy” (Kries, 28). The entire project has used more than 3500 sticks of Guadua bamboo. It signifies the construction revolution of a “cultivatable architecture”. “To speak of bamboo in such terms is not an exaggeration. The rapid growth of this plant makes it possible to cultivate and exploit it by means of plantations without damaging the environment” (Oprins, 104). In spite of that, the cost of this spectacular pavilion remains financially modest in comparison with other pavilions in the World Expo. This bamboo structure has become a landmark in sustainable architecture.

Figure 17 ZERI Pavilion (Kries, 23)

These precedents have influenced our bamboo pavilion design, named “The Breathing Structure”. The site chosen is in Toronto’s Harbourfront, adjacent to Queens Quay and Power

Plant. It becomes part of a redevelopment of linking the city into the water through the extension of the East Pier of the Queens Quay Harbour. Partly inspired by the Pantheon, the pavilion is distinguished with a large suspending roof spanning 11 meters, featuring an opening at the centre with a diameter of 1.5 m. Without the classical conjoining point at the centre, this unconventional opening would normally causing structural unstableness, which is overcome by adding steel cables bolted to the ground on the outer perimeter. All the loads are supported by 8 guadua bamboo columns. This open design allows for flexible seating arrangements account for numerous programme possibilities. In addition to the pavilion, there are rows of bamboo arches – bended bamboo structure imitating a bamboo forest, which have seating areas within.

Figure 18 Precedences for Bamboo Arches (Kries, 218, 251)

The axis of the pavilion leads one from Queens Quay West straight into the water’s edge to experience the serenity that still exists even within a busy city. This pavilion offers a lace of solitude as well as a host of different amenities that could help bringing civic life into the edge of the city, pilling out even into the water.

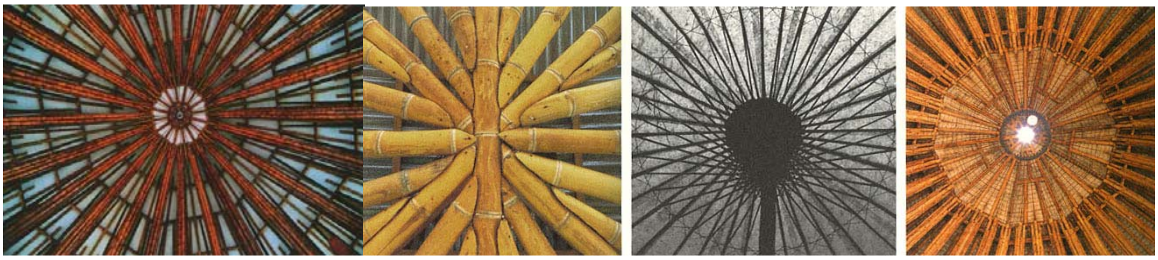

Figure 19 Conventional Roof Joints (Oprins, 104 and Kries, 208)

Figure 20 Steel Cable Reinforcing and Connections (Gutierrez, 32)

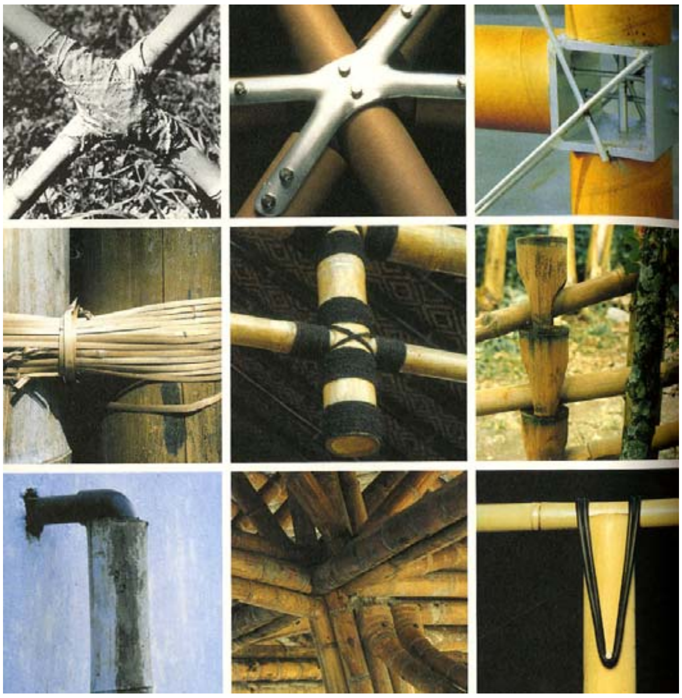

Figure 21 Other Bamboo Connections (Kries, 114)

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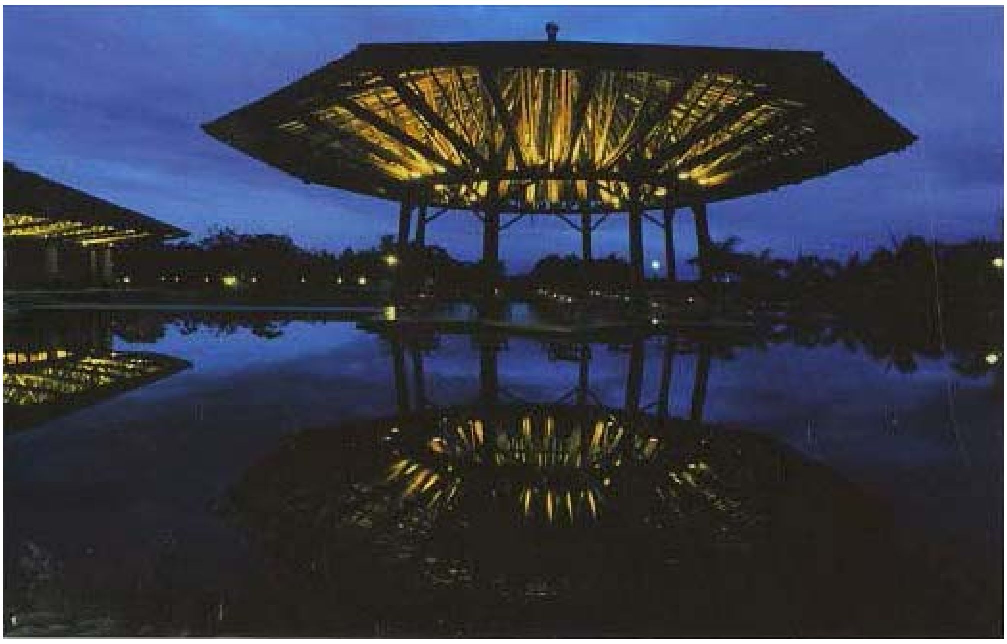

Figure 22 Other Precedence (Oprins, 104)