BAMBOO IN ARCHITECTURE AND CONSTRUCTION: BUILDING WITH BAMBOO

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Abstract

The paper presents different methods to build structures, roof or floor systems, building envelopes and partitions, using the bamboo plant. It also provides good examples on the use of bamboo in vernacular and modern buildings.

Key words: *bamboo structures, vernacular buildings, contemporary architecture*

1. BAMBOO IN VERNACULAR BUILDINGS

Irrespective of the geographical location, the bamboo is most frequently used in wall construction. Usually, the houses have a structural frame made from bamboo or wood. Since the wall does not bear the roof weight, no fundation is needed underneath. But in order to protect it against the rodents, insects and water, the wall is either lifted up above the ground (in stilt type constructions) or it has a base.

1.1. Wall systems

Dry type construction

a) Walls built with vertical culms.

Image 1: Building a wall with horizontal culms

In Thailand and Indonesia, the bamboo culms are arranged vertically, side by side, being pinned to the house framework. For a better weather protection, closely interlaced matting may be applied on the outer face.

b) Walls made from half round canes, positioned vertically or at 45 degree, nailed to the frame.

c) Walls built with horizontal culms (China)

d) Walls made of horizontal bamboo strips (2 mm thickness and 20-50 mm width) nailed on both sides of a wooden or bamboo frame.

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e) Walls built with mats of various thickness and weaved in different patterns are attached to the frame

f) Walls made of mats waved with split bamboo to become rigid

g) Walls built with interwoven mats (India)

Wet type construction

a) Plastered bamboo mat
Thin bamboo mats are pinned to the bamboo or wooden post, then coated with a stabilised mud plaster, creating an in-between air space.

b) Plastered „esterilla”
In Colombia and Ecuador, the split „esterilla” are fixed to the bamboo poles, then plastered. '*Esterilla*' derives from splitting the bamboo along its culm, opening and pressing it, then taking off the inner part of the cane. After being treated and dried, the elements are fixed to the bamboo or wooden frame and plastered with mud (Image 2).

Image 2: Wall made from plastered „esterilla”

Image 3: Bahareque walls

c) Bahareque wall
This type of wall, largely used in Latin America, is heavier and - when good handycraft is available – is able to withstand strong winds and earthquakes.Thin culms or bamboo strips, 4-5 cm in width and positioned at 5-7 cm intervals, are attached on both sides of the wooden or bamboo studs. The interstices are filled with a mixture of mud and straw (Image 3). In Colombia, where the resistant bamboo species are used (e.g. bambusaguadula), the bahareque wall houses has an extended life span.

Image 4: Bamboo board

d) Bamboo board wall
This technique, perfected in Colombia, uses round bamboo poles which are set at c 45 cm intervals, then covered with bamboo board on both sides and cement plastered. The system offers a better insulation thanks to the air spaces in the wall.

1.2. Floor construction

The beams are made from bamboo culms on which small size bamboo canes, bamboo laths, bamboo mats or bamboo board are positioned (Image 5).

Image 5: „Esterilla" mats, placed above the secondary bamboo beams

1.3. Roof construction

Split or whole bamboo culms may be used also as purlins, rafters and battens. The battens are nailed or fastened with ropes to the purlins. The roof is covered either with thatch or with bamboo tiles or shingles.

1.3. Roof coverings

- **Bamboo shingles** (Image 6)

The minimum pitch is 30°. The elements are usually 3-4 cm in width, processed from mature bamboo canes. The shingles are fixed to the 4 cm wide bamboo battens.

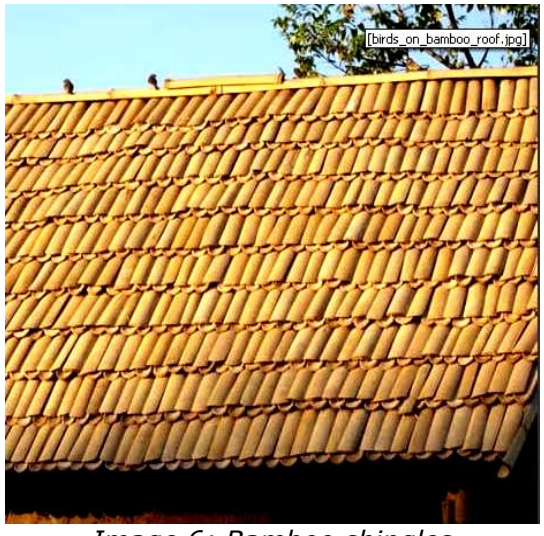


Image 6: Bamboo shingles

Image 7: Bamboo tiles

- **Bamboo tiles**

Flat tiles: the minimum slope of the roof is 30°. A 13 cm diameter culm is cut to a length of 30 cm. The diafragm is used to create a nib for the tile, in order to fix it to the batten.

Roman tiles (Image 7): the pitch should be at least 30°. Tiles with a curved section are obtained from round bamboo canes, split into two equal parts with the diaphragms being removed. The length of the tiles may be less or equal to the rafter length. One layer of tiles is fastened to the battens, side by side, with their concave side up and a second layer – having their concave side down - is set to interlock with the first.

1.5. Bamboo cables

The cables are made by twisting bamboo ropes around each other. The ropes are weaved from fine bamboo strings. Even Marco Polo, while exploring China, noticed that such ropes, more resistant than hemp ropes, were used for pulling the boats. Moreover, bamboo cables held up the Chinese bridge over Min-Chiang river. The bridge, constructed about 1000 years ago, was ca 2.7 m in width and 255 m long.

When wet, the resistance of a bamboo cable goes up, while that of the hemp rope decreases.

1.6. Examples of vernacular building

Ethiopia

An ethiopian hut, as pictured below (Image 8), is built on a bambooo skeleton and covered with a bamboo woven skin.

Image 8: Ethiopian hut

Image 9: A Tong house

India – Tripura (North-East India) – Tong House

The Tong house (Image 9) is a hill dwelling. In order to protect themselves from wild animals, the tribals have lifted the floor area with ca 1.5-1.8 m from the ground level.

Curilam village – India, west Tripura

The posts and the walls of the house are all made of bamboo. The wall consist of mats from woven bamboo strips, reinforced with bamboo laths. The facade may be covered with mud.

Image 10: House in Curilam village

Image 11: Dai houses

China - South of Yunnan Province - Dai houses

The Dai ethnic minority live mostly near the river in a climate characterized by heavy rainfall. Consequently, the house is raised on stilts (fig. 11), this technique being also a way to protect the inhabitants from insects, snakes and other dangerous animals. The skeleton of the house is made of timber, while bamboo is being used for floor and wall construction, as for purlins, rafters, ladders, handrails etc.

2. THE USE OF BAMBOO IN MODERN BUILDING PROJECTS

2.1. Trusses

Image 12: Assembling a Bamboo School Building

Image 13: Bamboo trusses are used to build a roof structure(Guyaquil, Ecuador, arch J. Morán)

2.2. Concrete reinforcements

Image 14: Bamboo reinforced concrete beam

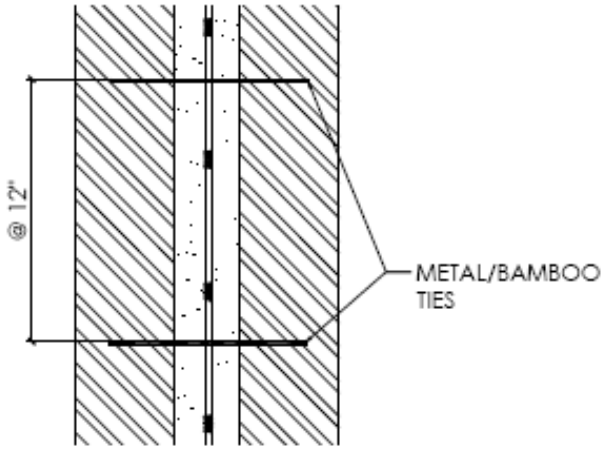
In the midst of the Second World War, in Japan, because of the steel shortage, steel reinforcements for concrete elements were replaced with bamboo.
When bamboo is to serve as concrete reinforcement, three or more twisted bamboo strips, taken from the peripherical zone of the culm, should be used, in order to increase its adherence to the concrete. The strips have to be made from nine months old bamboo culms, as the younger culms are more flexible than the older ones.Also, they need to be treated with asphalt or coal tar solution in order to gain water-resistance. But too much asphalt affects the adherence of the strip and the concrete.

Bamboo reinforced concrete slabs

In Ecuador, bamboo strips were used to reinforce slab foundations of prefabricated houses. Even after 10 years, no crack was visible in the slab.

2.3. Cavity wall construction with bamboo reinforcement

In order to get the best results, bamboo reinforcement for cavity wall construction requires a width of the cavity of minimum 7.5 cm and a distance between the splints axis of 15 cm. Also, horizontal rods, made of metal or bamboo, need to be used to secure the two layers of the cavity wall.



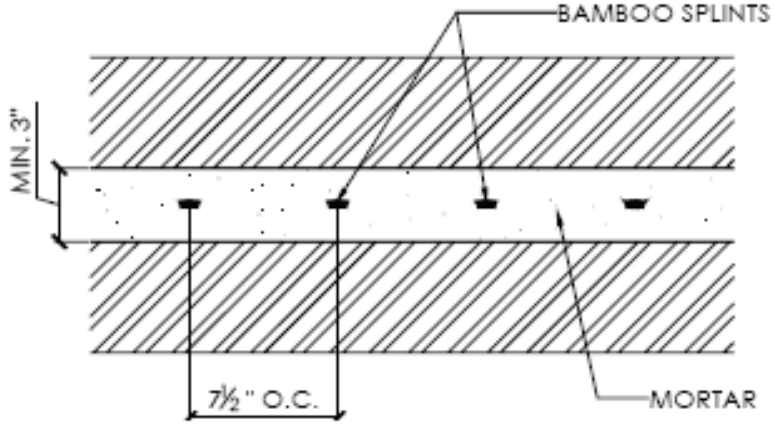


Image 15: Bamboo reinforcement for cavity wall construction

2.4. Examples of modern buildings

- Bridge, Pereira,Colombia, arch.Jorg Stamm

The bridge has a span of 52 m. The arches consist of 12 curved bamboo canes, tied together.

Image 16: Bridge, Pereira, Columbia, arch. Jorg Stamm

Image 17: Bridge built using GluBam

- Yan Xiao, Bridge, Hunan, China

A bamboo bridge, with a capacity of 90 tones, was erected in October 2007 in the village of Shangxun, Hunan Province, China. The superstructure was built with bamboo components, treated to gain weather resistance. Yan Xiao, the chief architect, professor at the University of Southern California, estimated that the life span of the construction at 20 years and approximated the cost of bamboo bridges as being half of those built with steel.

- Great bamboo wall house, China, arch.Kengo Kuma

Built nearby China's Great Wall, the main house materials are glass and bamboo.

Image 18: Great bamboo wall house, China, arch. Kengo Kuma, 2002

Image 19: Great bamboo wall house, China, arh. Kengo Kuma, 2002

The bamboo elements are used for the facade as well as for the interior bamboo wall. The latter, made from bamboo slats is a permeable wall which divides and unites the space at the same time, enriching it with fluidity and dynamism.

- Bamboo furniture house, Great Wall, Shui Guan, China, arch. Shigeru Ban

The house design follows the directions set by the previous "furniture house" projects: it is a single - storey construction, with an open- plan, having load bearing, modular and prefabricated furniture elements. Panels made from laminated bamboo strips are used to build the house structure, the facade and for the interior design, while laminated bamboo beams support the roof.

Image 20:Bamboo furniture house, Great Wall, Shui Guan, China, arch. Shigeru Ban, 2002

Image 21: Bamboo furniture house, Great Wall, Shui Guan, China, arch. Shigeru Ban, 2002

- Nomadic Museum, Zocalo, Mexico City, arch. Simon Velez

Conceived as a temporary construction, the museum houses Canadian artist Gregory Colbert's Ashes and Snow project. The building accommodates two galleries and three distinct theatres and is built using bamboo, shipping containers and different recycled materials.

Image 22: Nomadic Museum, Zocalo, Mexico City, arch. Simon Velez, 2008

Image 23: Nomadic Museum, Zocalo, Mexico City, arch. Simon Velez, 2008

Image 24: Nomadic Museum, Zocalo, Mexico City, arch. Simon Velez, 2008

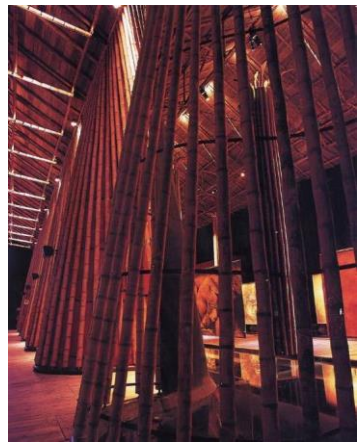
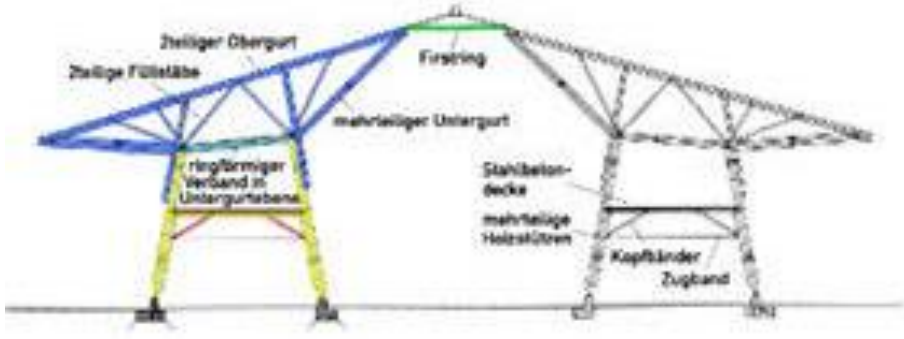


Image 25: Nomadic Museum, Zocalo, Mexico City, arch. Simon Velez, 2008

- ZERI Pavilion, Expo 2000, Hanover, arch. Simon Velez

The ZERI Pavilion, conceived for EXPO 2000, was set up in less than three months. The building materials were bamboo, wood, steel and concrete. The shape of the pavilion is decagonal, the circumscribed circle having 40 m in diameter. Its large roof with 7 m overhangs, is supported by 20 wooden pillars (each pillar is comprised of several bundled round timbers), arranged in two concentric circles. The studs and cantilevers are made from the bamboo specie guaduaangustifolia, with a diameter of 10-14 cm and a wall thickness of 1.1-2.2 cm. The beams, that supports the floor at the gallery level, consist of bamboo canes, as well as the base on which the concrete floor is poured – made of thin canes, 2-3 cm in diameter, laid down, side by side, to form a surface. Bamboo is also used as reinforcement for the roof 9 cm thick cement tiles.



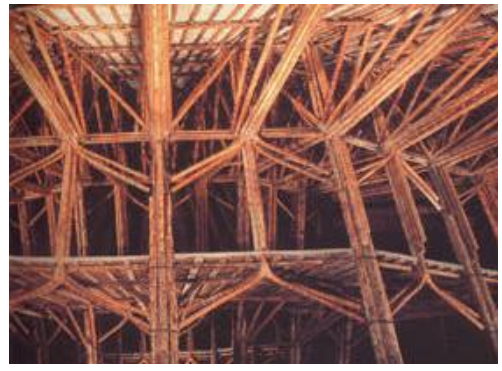


Image 26: ZERI Pavilion, Expo 2000, Hanover, arch. Simon Velez

Image 27: ZERI Pavilion, Expo 2000, Hanover, arch. Simon Velez

- Cultural Center Max Feffer, Pardinho, Sao Paolo, arch.Leiko Motomura

The building, with a footprint of 6000 m^2, houses a bamboo museum, a library and other spaces used for exhibition or as meeting places.

Image 28: Cultural Center Max Feffer, Pardinho, Sao Paolo, arch. Leiko Motomura, 2008

Image 29: Cultural Center Max Feffer, Pardinho, Sao Paolo, arch. Leiko Motomura, 2008

- METI School, Rudrapur, Bangladesh, arch. Anna Heringer, Eike Roswag

The school is built in Rudrapur, Bangladesh for a poor rural community, by the villagers and local craftsmen, together with the volunteer architects from Europe. The project received the 2007 Aga Kahn Award for Architecture.

The foundation is made with brick, the ground floor walls are built with loam and straw, bamboo being used only for the ceiling and first floor construction.

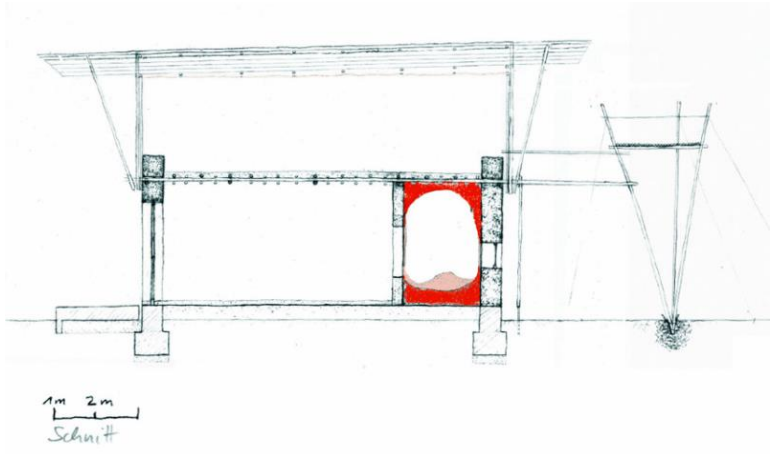


Image 30: Cross section (www.archsociety.com)

Image 31: METI School, Rudrapur, Bangladesh, arch. Anna Heringer, arch. Eike Roswag

Figure 32:METI School, Rudrapur, Bangladesh, arch. Anna Heringer, arch. Eike Roswag

Figure 33: METI School, Rudrapur, Bangladesh, arch. Anna Heringer, arch. Eike Roswag

Image 34: *METI School, Rudrapur, Bangladesh, arch. Anna Heringer, arch. Eike Roswag*

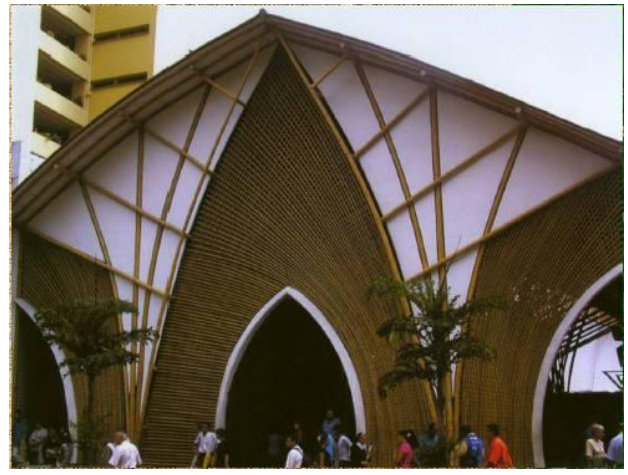


Image 35: Church, Pereira, Columbia, arch. Simon Velez

- Church, Pereira, Columbia, arch. Simon Velez

The load bearing structure is built with full length curved bamboo canes (guadua species), each arch being composed of five guadua culms, fastened with transverse braces to avoid buckling.

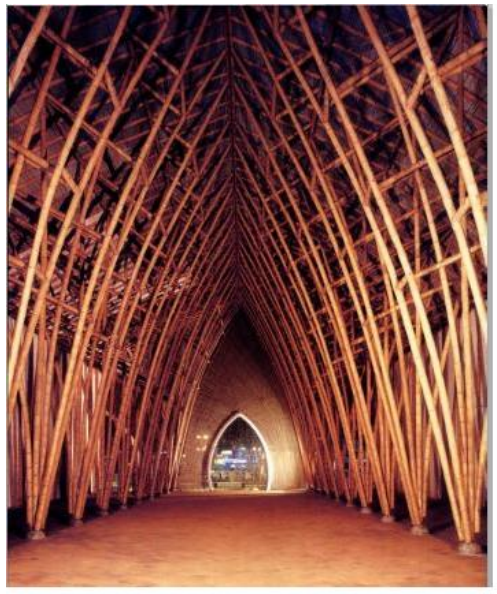


Image 36: Church, Pereira, Columbia, arch. Simon Velez

Image 37: Church, Pereira, Columbia, arch. Simon Velez

- HPP Hentrich-Petschnigg& Partners KG, Car park, Leipzig Zoo

A bamboo cladding was chosen for this five-storey construction, in order to fit with the building site. The facade consists of vertical bamboo culms, 10-12 cm diameter, fastened to a steel frame with adjustable braces and positioned at 7.5 cm intervals. Thus, the sunlight penetrates the exterior wall, illuminating the wooden walkway that surrounds every level of the car park and that is placed behind the bamboo screen.

Image 38:Car Park, Leipzig Zoo, arch. HPP Hentrich-Petschnigg& Partners KG, 2004

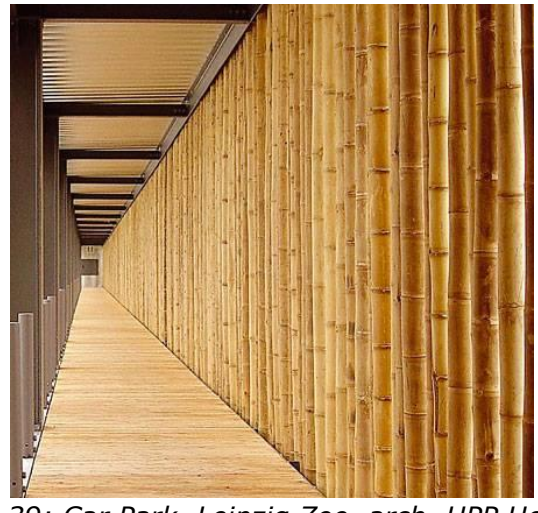


Image 39: Car Park, Leipzig Zoo, arch. HPP Hentrich-Petschnigg& Partners KG, 2004

- Spatial structures

A team of architects and engineers calling themselves Bamboo Space considered the tubular shape of the bamboo canes as ideal for building spatial structures. They created a type of connection which is light and consists of a spherical steel knot and steel tubes with a conical termination. This connection is suited for temporary construction. The steel tubes are inserted into the bamboo canes and fixed with bolts.

Image 40: „Prototipo Mariposa", National University of Colombia

Image 41: „Prototipo Mariposa", National University of Colombia

Illustration source

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