Building with Bamboo

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BUILDING WITH BAMBOO

Design and Technology of a Sustainable Architecture

Third and revised edition

Birkhäuser
Basel

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II Built Examples

I

The Technology of Bamboo Building

1 The Material

Types of Bamboo

The word “bamboo” was introduced by Carl von Linné in 1753. Bamboo is a grass plant like rice, corn and sugar cane. Different to these, the lignin of its tissues becomes after some years a structure as hard as wood, but more flexible and light. Bamboos, in their wild form, grow on all of the continents except Europe, from 51° north to 47° south. There are tropical and subtropical bamboos that thrive in different ecological niches, from cloud forests with humidity levels above 90% like the *Guadua angustifolia* in the Chocó Department of Colombia, to semi-arid zones of India (*Dendrocalamus strictus*). The majority of species are found in warm zones with humidity levels of over 80%, in tropical cloud forests, and in clayey and humid soils; for this reason they are often found near water. A few grow in dry climates or over 4000 m above sea level. In China and Japan there are also species that can survive temperatures below zero degrees. Approximately 1200 species exist, of which there are 750 in Asia and 450 in America. Of these last, the greatest diversity is found in Brazil (Hidalgo, 2003). It is estimated that 37 million hectares are covered with bamboo forests: 6 million in China, 9 million in India, 10 million in ten countries of Latin America and the majority in Southeast Asia (Lobovikov et al., 2007). Since antiquity, bamboo has been a construction material used to build basic habitats to complex structures; it has formed part of a set of elements that were an essential part of cultural development in Asia and America. In tropical zones, the bamboos most commonly used in construction are the *Bambusa, Chusquea, Dendrocalamus, Gigantochloa* and *Guadua*. Those of the group *Phyllostachys* prefer temperate zones.

The following is a list of the bamboos most commonly used in construction. Their characteristics are briefly mentioned, with the proviso that data can vary depending on local conditions. More information on the species can be found in Farrelly (1984), Young and Haun (1961) and McClure (1966).

Bambusa

- *Bambusa balcoa*
  Height: 12–20 m. Diameter: 8–15 cm.
  Origin: India.
  Note: internode thickness of up to 3 cm.
- *Bambusa disimulator*
  Height: 12 m. Diameter: 6 cm.
  Origin: Southern China.
  Note: fine and very hard internode.
- *Bambusa edilis*
  Height: 20 m. Diameter: 16 cm.
  Origin: China.
- *Bambusa polymorpha*
  Height: 27 m. Diameter: 15 cm.
  Origin: China, Bengal, Burma.
- *Bambusa stenostachya*
  Height: 22 m. Diameter: 15 cm.
  Origin: China.
- *Bambusa vulgaris*
  Height: 18 m. Diameter: 10 cm.
  Origin: Asia, Americas.
  Note: high starch content.

- *Bambusa bambos (L.) Voss*
  Height: 30 m. Diameter: 15–18 cm.
  Origin: Southeast Asia.
  Note: thick shell.
- *Bambusa nepalensis*
  Height: 20 m. Diameter: 10 cm.
- *Bambusa oldhami Munro*
  ("Green bamboo")
  Height: 6–12 m. Diameter: 3–12 cm.
  Origin: Taiwan.
  Note: strong green colour, short internodes.
- *Bambusa vulgaris, Schrader ex Wendland*
  Height: 6 – 15 m. Diameter: 5 – 10 cm.
  Origin: Southern China.
- *Bambusa vulgaris, Schrader ex Wendland, var. striata*
  Origin: Southeast Asia.
  Note: mutation of *Bambusa vulgaris* with yellow-gold colour and green stripes.

Chusquea

- *Chusquea culeou*
  Height: 6 m. Diameter: 4 cm.
  Origin: Chile.
  Note: It grows in the southernmost zones of the planet, and has a very strong culm.
- *Chusquea culeou Desvaux* ("coligüe", "colihue" or "culeú" in Chile)
  Height: 4–6 m. Diameter: 2–4 cm.
  Origin: Central America, South America.
  Note: solid stalk, yellow colour.
- *Chusquea quila Kunth* ("quila" in Chile)
  Origin: Chile.
  Note: solid stalk.

Dendrocalamus

A group of bamboos with many varieties; they grow very tall and are important for construction.

- *Dendrocalamus balcoa (Bambusa balcoa)*
  Height: 20 m. Diameter: 20 cm.
  Origin: Southeast Asia and India.
- *Dendrocalamus giganteus*
  ("Giant bamboo")
  One of the largest bamboos, it has a diameter of 30 cm or more. It grows up to 20 cm per day and reaches a height of more than 30 m. The species is originally from India, Burma, Sri Lanka and Thailand, and is used for large structures, for furniture and for the production of paper.
- *Dendrocalamus asper* ("Bucket bamboo" in Brazil)
  Resistant to below-zero temperatures. It does not grow as much as Dendrocalamus giganteus; reaches a height of 25 m and has a diameter of 20 cm. Its stalk is very hard and cracks less than D. giganteus while drying. Excellent for construction.
- *Dendrocalamus latiflorus*
  Height: 20 m. Diameter: 20 cm.
  Origin: Taiwan, Southern China.
  Note: internodes of up to 70 cm; very thick stalk (more than 2.5 cm).

Gigantochloa

- *Gigantochloa apus*
  Height: 16 m. Diameter: 10 cm.
  Origin: Malaysia and Indonesia.
- *Gigantochloa atroviolacea*
  ("Black bamboo")
  Height: 13 m. Diameter: 8 cm.
  Origin: Malaysia and Indonesia.
- *Gigantochloa levis*
  Height: 16 m. Diameter: 10–15 cm.
  Origin: Philippines.

Guadua

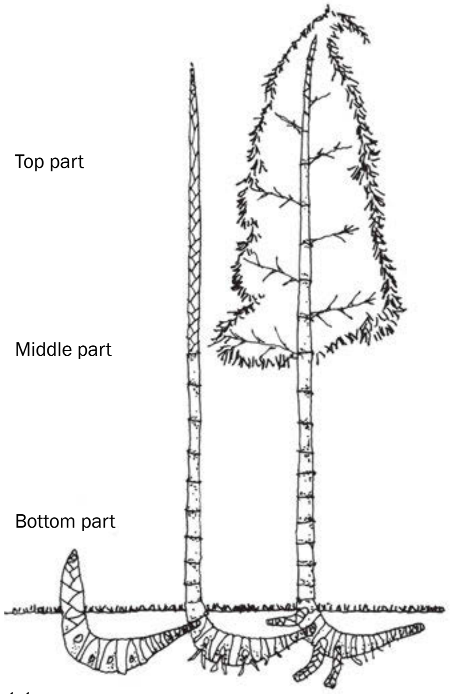
The guadua is a type endemic to South America. Its name was given by Karl Sigismund Kunth in 1822, who took it from the term "guadua" used by the indigenous peoples of Colombia and Ecuador. The forests of guadua are called "guaduales" (*2.4*).

- *Guadua angustifolia Kunth*
  The guadua most commonly used in construction; it has a diameter between 9 cm and 12 cm, exceptionally can reach up to 21 cm. Its daily growth can be 12 cm per day, and after 3 months it reaches 80% to 90% of its definitive height, which can be between 15 m and 30 m high. Among its varieties are bicolour Londoño and nigra Londoño, which have variations of form according to the climate: "onion" with internodes that are long and efficient in tension; "club" with internodes more closely spaced and efficient in compression; "castle", which is less efficient in compression and more suitable for the elaboration of planks; and "goitred", characterised by its irregular stalks.
- *Guadua aculeata*
  Height: 25 m. Diameter: 12 cm.
  Origin: Mexico to Panama.
- *Guadua chacoensis* ("tacuaruzú")
  Height: 20 m. Diameter: 8–12 cm.
  Origin: northern Argentina and Bolivian tropics.
- *Guadua paniculata Munro* ("pretty")
  Height: 10 m. Diameter: 3 cm.
  Origin: Bolivian tropic.
  Note: the upper part is solid, while the lower has small openings.
- *Guadua superba Huber* ("tacuarembó")
  Height: 20 m. Diameter: 9–12 cm.
  Origin: Bolivian tropics.
  Note: cracks easily.

Phyllostachys

The bamboos of this group grow in temperate zones and have the characteristic of forming nodes in zigzag or other irregular forms. Is originally from China, nevertheless many species were cultivated in Japan, the Americas and Europe.

- *Phyllostachys aurea* (*2.7*)
  Height: 5 m. Diameter: 2 cm.
  Origin: China and Japan.
- *Phyllostachys bambusoides*
  Height: 22 m. Diameter: 14 cm.
  Origin: Japan.
- *Phyllostachys nigra, var. henonis*
  Height: 16 m. Diameter: 9 cm.
  Origin: China, introduced into Japan and the United States.
- *Phyllostachys pubescens* ("Moso", "Mao Zhu")
  Height: 21 m. Diameter: 17 cm.
  Origin: China, introduced into Japan and the United States.
- *Phyllostachys vivax*
  Height: 21 m. Diameter: 12 cm.
  Origin: China.



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<table>
<tr><th></th><th colspan="2">USES ACCORDING TO THE PLANT SECTION</th><th>DESCRIPTION</th><th>HEIGHT</th><th>LENGTH</th></tr>
<tr><td>Leader</td><td colspan="2">Returns to the earth as organic material</td><td>Apical part of the plant</td><td>20 m</td><td>1.20–2 m</td></tr>
<tr><td>Stick</td><td colspan="2">Structural straps for roofs, and guides for transitory cultivations</td><td>Part of the stalk with the smallest section</td><td>18 m</td><td>3 m</td></tr>
<tr><td>Top</td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Middle</td><td colspan="2">In structures such as roof purlins, scaffolding, structural columns for greenhouses</td><td>Because of its diameter, it is the most marketable part of the upper stalk</td><td>15 m</td><td>4 m</td></tr>
<tr><td colspan="2">Elaboration of planks, slender columns and beams</td><td>Part of the stalk most used, for its diameter</td><td>11 m</td><td>8 m</td></tr>
<tr><td>Bottom</td><td colspan="2">Columns in civil works, greenhouses and fences</td><td>In this part, the stalk has the greatest diameter. It is the most resistant part of the plant</td><td>3 m</td><td>3 m</td></tr>
<tr><td>Rhizome</td><td colspan="2">Sculptures, furniture and children’s toys</td><td>Network of underground stalks</td><td>2m</td><td>2 m</td></tr>
<tr><td>USES ACCORDING TO AGE</td><td>30 days
Food</td><td>1 year
Basketwork</td><td>2 years
Planks, Strips, Laths</td><td colspan="2">3 to 4 years
Civil Structures, Floors, Laminates</td></tr>
</table>

Positive Environmental Effects

Biomass Production

Bamboo is a rapid-growth natural resource that can produce much more dry biomass per hectare per year than eucalyptus. The production of bamboo biomass depends on many factors and therefore varies significantly. According to Liese and Düking (2009), the production of dry aerial biomass from *Bambusa bambos* in Southern India reaches 47 tonnes per hectare per year if it has been cultivated, while that of *Chusquea culeou* of Central Chile reaches only 10.5 tonnes per hectare per year. According to Riaño et al. (2002), starting from new cultivation, the *Guadua angustifolia* in Cauca Valley, Colombia, produces approximately 100 tonnes per hectare in six years.
According to Cruz Ríos (2009), the production in one plantation of *Guadua angustifolia* reached up to 594.2 tonnes per hectare in seven years.

Reduction of Soil Erosion

Bamboo has a dense network of roots that anchors earth and helps to lessen erosion due to rain and flooding.

Water Retention

One hectare of *Guadua angustifolia* can retain over 30,000 litres of water (Sabogal, 1979).

Regulation of Hydraulic Flow

Retaining water in its stem, bamboo conserves water in the rainy season, using it later in the dry season.

Temperature Reduction

Thanks to their leaves, bamboo forests reduce air temperature through water evaporation.

Sequestering of CO_2

Plants that assimilate CO_2 for photosynthesis, storing it in their biomass, make an important contribution to the global climate. Because of its rapid growth, bamboo can take in more CO_2 than a tree. The *Guadua angustifolia Kunth* takes in 54 tonnes of CO_2 per hectare during its first six years of growth (Londoño, 2003). This might be a relevant fact for international greenhouse gas emission allowance trading. However, this fact is only valid if the bamboo plant that has sequestered the CO_2 is transformed into products with long life spans.
According to Cruz Ríos (2009), the absorption of carbon at one plantation of *Guadua angustifolia* is 149.9 tonnes per hectare in the first seven years, which is an average of 21.41 tonnes of carbon per year per hectare, and a natural growth of *Guadua angustifolia*, with a density of 5755 plants per hectare, has absorbed a total of 132.6 tonnes of carbon. After six years, the bamboo stock stabilises the quantity of carbon absorption, due to the fact that this is totally vegetative development. “Being a plant that self-regenerates, bamboo has, with adequate management and harvest, a permanent CO_2 absorption, which does not happen with other species. The guadua is planted only once and with good management converts into a permanent plantation.” (Cruz Ríos, 2009)
According to Janssen (1981), the production of bamboo uses 300 MJ/m^3, compared with 600 MJ/m^3 for wood.

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Different Uses

The use depends on the type of bamboo, its age and the part of the plant. Figure *1.1* describes the uses for the bamboo *Guadua angustifolia Kunth*.

Due to its favourable mechanical characteristics, great flexibility, rapid growth, low weight and low cost, bamboo is a construction material with many applications. It is estimated that one billion people live in houses constructed from bamboo (Liese and Düking, 2009); for example, in Bangladesh over 70% and in Guayaquil, Ecuador, 50% of the population uses it in construction. In seismic zones bamboo construction is preferred due to its lightness and flexibility. In humid tropical zones bamboo is used in construction since it is a local, cheap and easily handled material; furthermore in these areas it allows walls with low thermal mass.

The ideal use of large bamboos like *Guadua angustifolia* depends on their age. In their first days, bamboo hearts are used as food; between six and 12 months, strips extracted from the external zone of the cane are ideal for making fabrics that can act as board-like components (*1.2* and *1.3*). Because of the friction between their elements they form stable structures. Fine strips braided into large ropes were also used in nautical applications. These have a greater resistance to abrasion than those of hemp (Dunkelberg, 1985). At the age of two years the canes can be used for making plank boards (see Chapter 7, "Canes, Planks, Strips, Laths and Belts") and normally between three and five years the stalks are ideal for use in construction.

The majority of traditional houses in the rural zones of warm humid climates where bamboo grows, are constructed of this material. Figures *1.4* and *1.5* show examples from Indonesia and India. Due to walls of bamboo planks there is sufficient air circulation.

A typical use of bamboo canes is in the construction of scaffolding. In Asia these are found with heights of more than 40 storeys *(1.6* and *1.7)*. Bamboo strips of 1 × 1 cm arranged in parallel can be used as a structural beam. The example on pp. 78–79, Ubud Guesthouse, has beams of 12 cm in diameter, composed of approximately 100 laths secured with leather.

Another common use in regions where bamboo grows is for crafts and everyday objects *(1.8* to *1.11)*, musical instruments *(1.12* to *1.14* and *1.20)* and furniture *(1.15* to *1.17)*.

New is the experimental use in vehicles like bicycles, cars and buses: figure *1.18* shows the design of a bamboo buggy by

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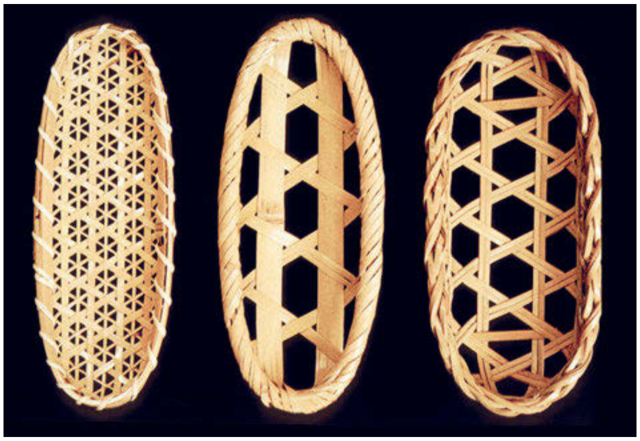

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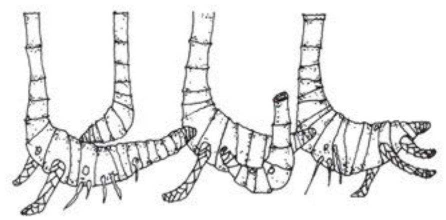
Jörg Stamm; Julio César Toro has designed and built a rural bus for 20 people *(1.19)*. To make the body, the floor and the railings, he used 40 linear metres of guadua and for the roof he used 63 small boards of macana. The bumper was made of laminates of guadua.

In the 1980s, China pioneered the industrial development of the use of bamboo in laminates (see Chapter 7, "Laminated Elements"). Fibres treated with a viscose process are being used in China similar to those of wood cellulose, resulting in a very resistant and smooth fabric.

The industrial production of paper using bamboo pulp was developed in India around 1910 (Hidalgo, 2003). Thomas Edison tested thousands of vegetable fibres for use as filaments in light bulbs and found that the fibre of a bamboo from Japan was the best. It lasted 2450 hours when lit. After this discovery, the General Electric Company used this type of filament for 14 years.

A scientist from China studied the different applications of bamboo, classifying 1386 different uses (Lübke, 1961). In a similar way, a thorough investigation into the various uses of bamboo was published by the Swiss Hans Spörry. During his travels in Japan between 1890 and 1896, Spörry collected bamboo items and catalogued them, thus gathering a collection of about 1500 bamboo objects. His 1903 book publication *Die Verwendung des Bambus in Japan* (The Use of Bamboo in Japan) lists 1048 uses of bamboo for Japan alone (Hebel, Heisel, 2017).

2 The Plant



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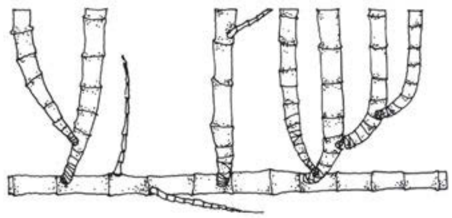

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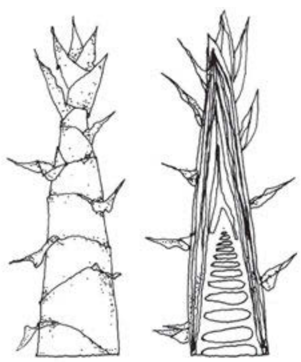

2.3

2.4

The bamboo stalk grows directly from the rhizome (subterranean stalk). The rhizomes of pachymorphic bamboos grow in all directions, forming a three-dimensional network with a height of up to 2 m *(2.1).* The stems grow very close together, forming a bush *(2.9).* Bamboos with leptomorphic rhizomes grow from a horizontally lineal rhizome *(2.2).* There are also combinations of these types.

Bamboo is characterised by having all of the nodes and internodes of the adult culm compressed in the heart (sprout); only the internodes stretch during its growth, beginning with the lower ones *(2.3).* In the same way, the difference in diameter of the nodes is maintained when the cane reaches its definitive height, obtaining its slightly conical form. The mother plants (first generation plants) have a smaller diameter; in the following three generations, they thicken a little each time (Londoño, 2003). The *Guadua angustifolia Kunth* grows up to 21 cm per day and in one month reaches 80% of its maximum height, which it completes in five more months, reaching between 15 m and 30 m (Londoño, 2003). The productivity is between 1200 and 1350 canes per hectare per year. The process of lignification (becoming woody) takes between four and six years; after this period its vascular bundles close and dry out, and the stalk can be used for construction.

During the growth state, the humidity content can be up to 80% in the first part of the stalk, and after four to six years, when the stalk is hard, lowers to approximately 20%. Bamboos which grow on inclined land with little water are stronger and, therefore, more appropri-

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ate for construction than bamboos that grow in flat humid areas. They are stronger in compression since their tissue is denser and has more fibres.

Bamboos are grass plants that have very long flowering periods, with a cycle between two and 100 years (for large bamboos between 40 and 80). The flowering of a species can be gregarious; that is, it blooms at the same time all over a continent, or the world, generally only once in its lifetime. Afterwards, the plant dies (*2.7* and *2.8*). The *Guadua angustifolia* does not die after its yearly flowering period, which is associated with strong summers, be they occasional or continuous (Londoño, 2003). The colour of bamboo canes is generally green; after becoming woody they change colour to between yellow and brown. Black bamboo and *Bambusa vulgaris* (*2.10* and *2.11*) are exceptions.

Reproduction can be by:

- Chusquin method (small plants that emerge from the mother rhizome).
- Parts of the stem with node and bud. If a part of the stem with more nodes is used, one must open the internodes so that water can enter.
- Parts of the rhizome.
- Seeds.

3 Cutting, Drying, Treatment and Storage

3.1

3.2

Bamboo contains a large quantity of starch, which attracts insects, especially when the level of sap is high. Also the presence of humidity can cause the appearance of fungus and lichens. To guarantee durability in bamboo construction elements, it is important to take into account good procedures for cutting, drying and treatment.

Cutting

Cutting bamboo is done with a machete or saw directly above the first or second aboveground node, keeping in mind that the cut should be inclined, to avoid the penetration of rain into the rhizome, thereby rotting it. It is advisable to make the cut during the dry season when the stems have minimum humidity. Field observations have demonstrated that a correlation exists between the humidity content of the canes and the phases of the moon, and that there is also a correlation with the humidity content of day and night. The humidity of the plant interior is lower in the waning phase of the moon and in the early hours of morning, before the sun rises. The optimum age at which to cut *Guadua angustifolia* for structural use is between three and five years, when its tissue is hardened.

Drying in the Bush

The most common method of curing is to dry in the bush: one places the culm with its branches and leaves from the ground onto a stone, maintaining its vertical position. This is done for a minimum of four weeks so that it dries through evaporation. Afterwards, the branches and leaves are cut and the culm is

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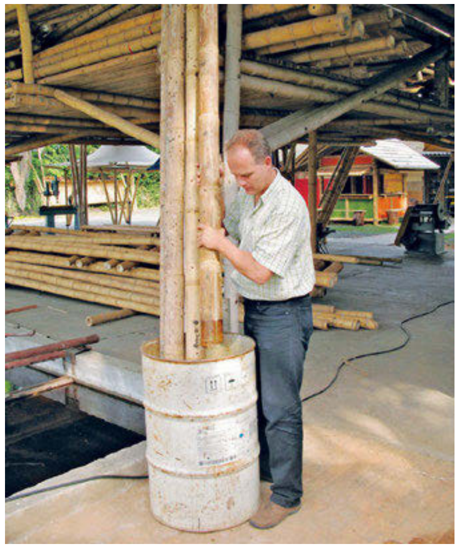

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left to dry further in a covered, well-ventilated space.

Air Drying

The simplest method to dry the canes is to arrange them in a form similar to a tripod, exposing them to the sun and wind *(3.1).* The process of drying is optimised in a greenhouse with a plastic enclosure. It is favourable to open it at night so that the less humid air can enter, and close it during the day. Figure *3.2* shows a method practiced by Ecobamboo, Colombia, where hot air is injected into the bamboo by a fan that transfers the heat from a solar collector, pushing it through a sleeve into the canes, which have already been longitudinally perforated.

Microwave Drying

One can use high-frequency electromagnetic waves to evaporate the humidity from the canes. This has the characteristic of drying from the inside out, as opposed to the other drying systems that work from the outside in. This method uses large equipments and a lot of energy.

Drying and Curing Using Heat

A primitive method of heat curing is to put the canes horizontally over live coals at a distance sufficient to avoid burning them with the flames. This method is very laborious and there is a great probability that the canes will crack.

Earth Curing

In rural areas of Bangladesh a simple method is used: the canes are laid in a slurry of clayey earth for some weeks. By this method the starch is extracted from the stalks (Chowdury, 1992).

Smoke Curing

Smoke in an enclosed space is most efficient for curing bamboo. Figure *3.3* shows an oven that was constructed by the author for the project shown in Chapter 12, "Earth Walls Reinforced with Bamboo", where the canes stayed between eight and twelve hours over a low-temperature fire. These ovens produced large amounts of smoke using humid leaves and fresh branches as fuel.

Cleaning the Surface

Steel wool has been widely used to clean lichens from the surface of bamboo. Nevertheless, this method turns out to be costly, slow and dangerous for the respiratory systems of the workers. Furthermore the use of metal sponges and brushes is not rec-

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3.7

ommended as it can weaken the shell. A more effective, inexpensive and healthy option is to use a hydrowash with a stream of high-pressure water *(3.4)*. The use of metal sponges and brushes is not recommended as it can weaken the shell.

Lime Protection

A simple solution to protect the bamboo surface against fungus, lichens and insects is to paint it with lime ($Ca(OH)_2$), which due to its low pH level acts as fungicide and insecticide. The lime paint does not last very long because it has low resistance to abrasion and erosion due to its low adhesive capacity. To augment it, one can first paint the cane with an asphaltic emulsion, throw sand over this and wait until the asphalt dries.

Preservation by Flooding the Internodes

A primitive method widely used in rural areas and known as “vertical sap diffusion” consists of putting the canes with branches and leaves in a vertical position in a container, perforating the diaphragms of the upper nodes until the penultimate one and pouring in the immunising agent from above *(3.5)*. If there are cracks or holes in the shell, one must first close them with paraffin or wax. Afterwards, one opens the last diaphragm so that the remaining liquid, which can be reused, escapes. The disadvantage of this method is that the poison also goes to the branches and leaves, contaminating the surroundings after their cutting. If the branches are cut before the immunisation process, this pollution is eliminated, but the preservation time takes much longer, as there is no enhancement of penetration through the suction by the evaporation of the leaves

Preservation by Immersion

An effective method to immunise the canes against insects and fungus is immersion in a liquid that functions as both insecticide and fungicide. It is necessary to perforate the wall of the canes in each one of its internodes (but not in a straight line, in order to avoid cracks) or, more intelligently, make a longitudinal perforation pushing an iron rod through all of its nodes; see *3.6*. Figure *3.7* shows the immersion pool where the canes are left submerged for several days. It is important that the canes are not too dry. The immunising salt does not enter into a totally dry skin of the cane, only the water does (the salt stays on the surface). The salt penetrates through osmosis, which only works if there is sufficient humidity.
There are many immunisation products on the market with a base of copper sulphate, sodium dichromate or zinc chloride. Cheap-

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er and less contaminating for its users is "pentaborate", which consists of 5% borax and 5% boric acid in a water solution. According to the experience of Jörg Stamm, it is sufficient in industrial processes to use 2.5% borax and 2.5% boric acid. Another proportion suggested by the National Bamboo and Guadua Investigation Centre, Colombia, is to use 2 kg of boric acid and 1 kg of borax in 100 litres of water.

Preservation by Injection

To use the injection treatment, one perforates all of the internodes to apply between 10 ml and 20 ml of the immunising agent per internode. It is necessary to seal each perforation afterwards. This method requires a lot of care since one must guarantee that the entire cane receives sufficient treatment; for this reason this method is not recommended.

Preservation by Pressure

An effective but more expensive variant is to pass the immunising agent by pressure through the longitudinal tissues of the cane; it is commonly called the "Boucherie method". In the last 20 years this method has been changed and perfected to arrive at a portable plant that permits treatment in the bush immediately after cutting; see *3.8*.

Surface Bleaching

One can use the sun to ensure that the surfaces of the canes are lighter and uniform in colour. Figure *3.9* shows a tripod-like structure where the canes are left in the sun and are manually rotated each day.

Surface Protection

In order to avoid deterioration of the exterior surface by ultraviolet rays and by rain, one can use commercially available paints with a base of linseed oil and beeswax, which close the open pores but do not totally block moisture transfer. One can also use commonly available oil-based paints, normally applied to wood.

Fire-Retardant Treatment

For this, one can use the same products that are used to protect wood.
One suggestion of the United Nations (1972) is to add the following to 100 litres of water:
– 3 litres of ammonium phosphate
– 3 litres of boric acid
– 1 litre of copper sulphate
– 5 litres of zinc chloride
– 3 litres of sodium dichromate
– a few drops of hydrochloric acid

Storage

Bamboo is a hygroscopic and porous material; it absorbs water in vapour and in liquid form. If the bamboo cane becomes wet, its shell will swell and its mechanical properties will diminish. For this reason the bamboo must be stored in a covered, dry and well-ventilated place.