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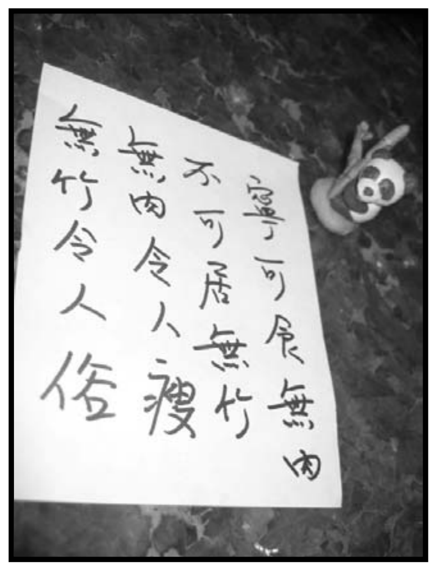
A Brief Overview of BAMBOO

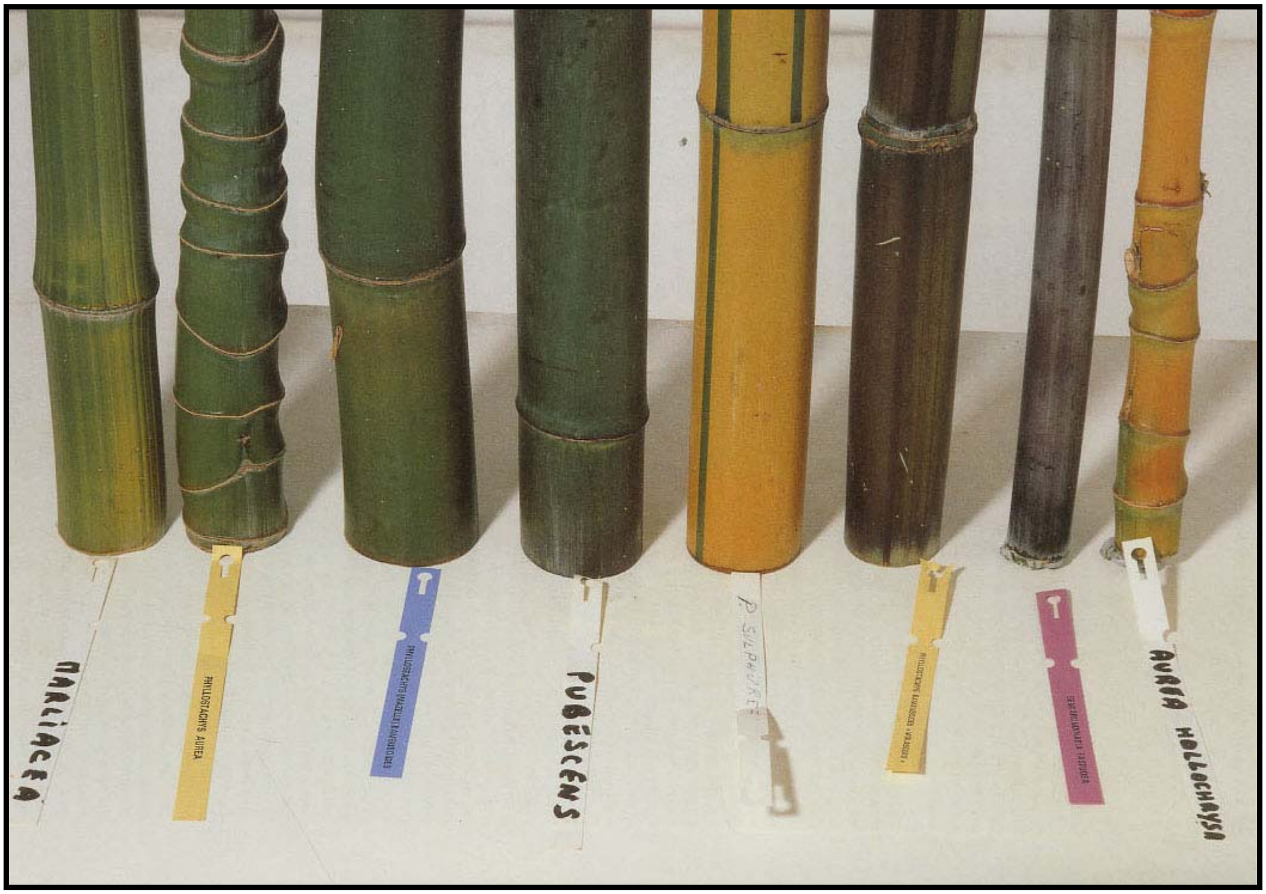
and Case Study: The Guadua Pavilion

<u>Lore:</u>

Eight hundred years ago, poet Pou Sou-tung wrote: “A meal should have meat, but a house must have bamboo. Without meat we become thin; without bamboo, we lose serenity and culture itself” (Austin, 20). That phrase still stands true in Chinese families today and is inextricably woven into the fabric of the Eastern culture. Traditionally, bamboo has provided; food, raw building materials, the thatch coving a house, sleeping mats, eating and drinking utensils, medicine, baskets, hats, farming tools, flutes, old Chinese books were inscribed by hand on strips of bamboo linked with silk. Paper from bamboo has been made into fans, used as a part of the sliding wall of a room, or umbrellas. Linking the East to the West are Gramophone needles, Edison’s filament for his first electric lamps, and the design of ships has its origin in the ancient bamboo sailing raft that is still used today. (Austin, 9-20)



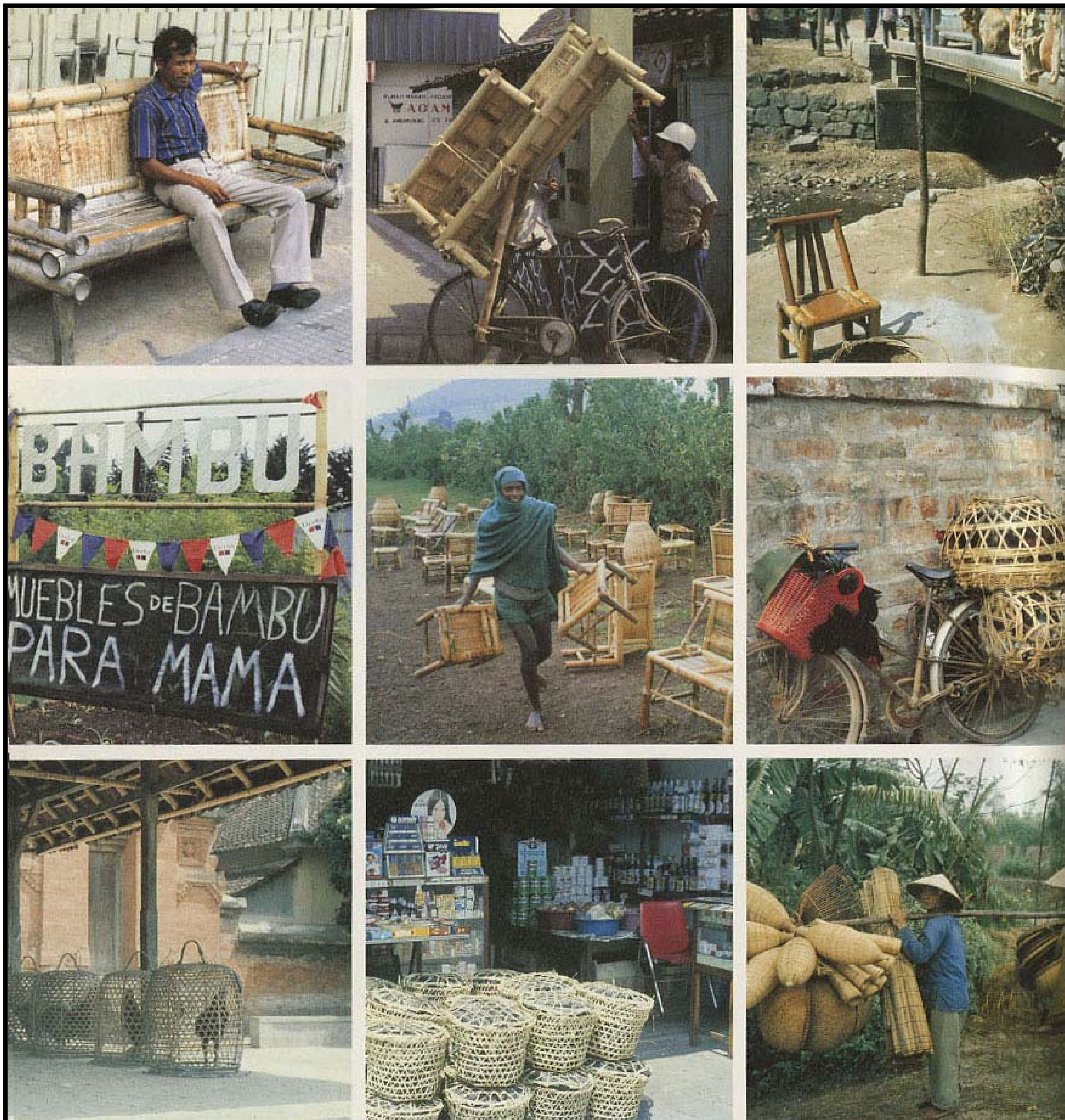
Pou Sou-tung’s Poem
(Elaine Lui, 2006).



Types of Bamboo (Vélez, 158)

Food (Oprins, 122)

Example of Food



▶ **Muttertag in Costa Rica**
Mothers' day in Costa Rica

▼ **In Asien werden aus gespaltenen Bambusstäben Tierkäfige hergestellt.**
In Asia, split bamboo is used to make animal cages

▲ **Bambusmöbel in Bali**
Bamboo furniture in Bali

▶ **Bambusmöbel auf dem äthiopischen Hochland**
Bamboo furniture in the Ethiopian highlands

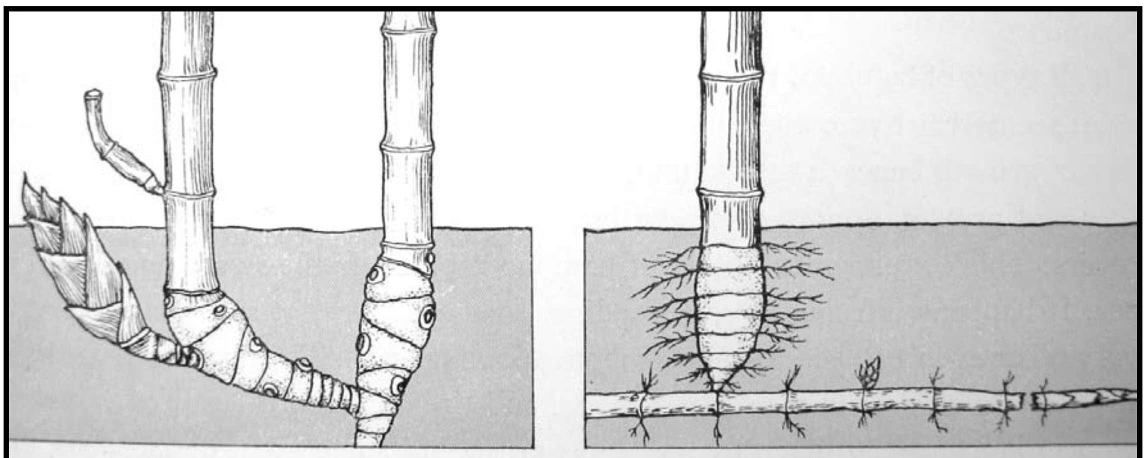
▲ **Bambusmöbel in China**
Bamboo furniture in China

▼ **Fischreusen aus Bambus, Vietnam**
Bamboo fish traps, Vietnam

Examples of Bamboo Usage (Vélez, 176)

Biology:

The biological characteristics of the bamboo is that they are grasses belonging to the family named *Poaceae* - previously named *Graminae* – which include about 65 families with 10,000 species. The bamboo subfamily is named the *Bambusoideae*.[1] As a type of grass called *monocotyledonus*, the plant have seeds with only one seed lobe, structures which contain a reserve of food for the sprouting plant. A grass stalk is usually hollow, named the internodes (which sometimes can be solid, depending on the species), while the nodes are the swellings on the stalk where the leaves sprout from. While the smaller leaves from the node carry out photosynthesis, the leaves on the culm (stalk) are larger and are not to be removed as its main function is to protect young bamboo. The root systems consist of two types: *monophodial* in warmer climates and *sympodial* in cooler climates. (Oprins,13 – 23)


Bamboo Growth Patterns: Sympodial (left) and Monopodial (right)

Sympodal and Monopodial Root Systems (Austin, 15)

The first type of bamboo named *monophodial,* the bamboo consist of a long underground rhizome with a single bud that develops each year on the alternate side of each node or joint. The sprouts appear above ground at a distance from one another and although less than 10percent of the buds germinate, and a smaller proportion fail to grow to full size, the yield is still quite large.

For *sympodial*, underground stems named *rhizomes* which grow in short segments and erect stems above the ground, resulting in a formation of a clump. Each growing point of the rhizome produces roots which are longer and thinner then the bamboos, forming a network of roots with subsidiary nodes which can rapidly overtake a large area. The *monophodial* bamboo does almost all its growing in the first month, while sprouts may take two month intervals to appear, its season in Japan being mainly between March to June. The *sympodial* bamboo takes 80 to 120 days reach its full height in a single season, living for up to 10 years. The growth of the bamboo generally reaches its full height and maturity in the first year; due to this speed, the culm has no time to provide sustenance for itself, thus is dependent upon the nourishment it receives through the rhizome and 'mother bamboo.' It has been recorded that during a single day, by the Japanese authority Koichiro Ueda, the Moso grew 46.8 inches while the Madake grew 47.6 inches. (Austin, 193 – 198)

An asexual plant – reproduction without pollination, its flowering cycle occurs in long intervals every 60 to 120 years; then the plant dies. The reason for this is that instead of growing leaves, the plant grows flowers and no longer has the ability to take in water and nourishment. In this process, seeds are produced, but he causes of flowering are still a mystery as the act of flowering occurs in long intervals and irregularly. Interestingly, the periods of flowering occur with the same species regardless of the continent on which bamboo resides; demonstrating that the common origin of the bamboos and the strength of the inherited habits of the genus. New culms will grow for at least two more generations and will flower until one new system that does not flower appear; it would now be independent of the parent rhizome. If left unattended, it would take ten years for the new culms to reach the size of the previous generation. (Austin, 200)

Environmental Benefits:

Mainly found growing between the Tropics of Cancer and Capricorn, the bamboo can actually face harsh winters as well providing a root system of rhizomes to combat erosion on slopes and open spot sin the woods. Colors of bamboo include tints of green, gold, black or red that may include streaks and textures, while leaves are green and can be streaked with gold cream or white. No only does the bamboo have aesthetic application capabilities, the bamboo has a capacity to recycle carbon dioxide (12 ton/hectare) and purifies the air, which produces 35 percent more oxygen than tress in the same situation (Oprins, 55). As a ground cover, it requires little care only that controlling methods of this root system include setting up a rhizome barrier with sufficient overlap between the roots of the particular species. They also protect against soil erosion, become effective windbreaks due to its flexibility, as watersheds in its toleration to constant flooding catching rainwater and combating erosion, important for reinforcing river and lakes as 80 percent of its roots are located in the topsoil. Bamboo can also transform lacking soil conditions or wasteland into productive and arable land due to its ability to grow in poor soil. Harvested for biomass, the leaf litter and root system combine to contribute to the build-up of organic carbon, increasing the amount of micoflora that acts as nutrients to other plants. In addition it improves the water management increasing its water capacity and acidity as well as purifying waste water.

A Building material:

A fast growing plant that can withstand below freezing temperatures, stabilize the earth on a riverbank in Louisiana, realistic creations of zoo habitats and food for animals, the bamboo is a rapidly growing, tall evergreen screen, useful for creating privacy in an suburban environment. Bamboo is flexible yet tough, light, but very strong. Bamboo's properties, according to Goldberg, has greater strength then steel in tension and is stronger than concrete in compression (34). In comparison, the energy required to produce a unit of a building material with a certain level of load-bearing capacity in units of MJ/m^3 or N/mm^2: while steel requires 1,500, concrete needs 240, wood 80 and bamboo only 30 (Kries, 155). This proves the enduring sustainability of the bamboo. Harvested within tree to five years as opposed to some ten to twenty years that are required fro softwoods, it is an ideal resource for the wood and paper industry. It is considered by Oprins Plant to use bamboo as a source for biomass in the wood industry for fibre and chipboard, as well as for biochemical products or as a biological energy source for Europe (Oprins, 58).

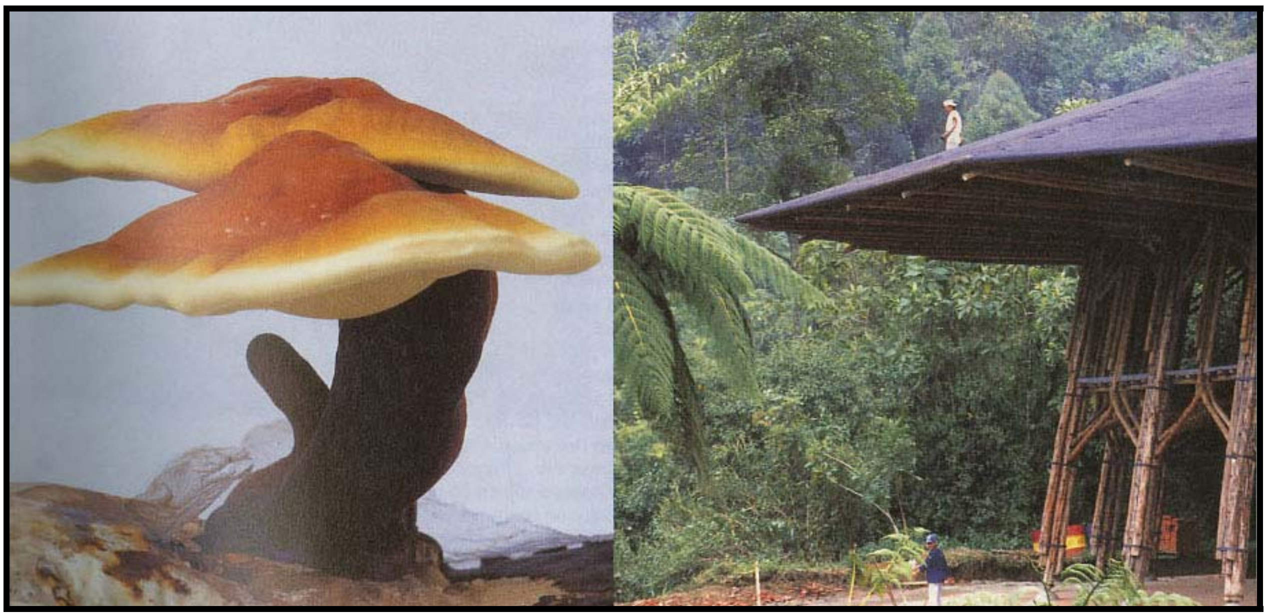
Examples of Joint Connections

(Vélez 114)

CASE STUDY: The Guadua Pavilion

Materials:

The aim of the architect, Simón Vélez, was to only use varieties of timber and bamboo that naturally grew in the region. He also included a previously unused low-density wood called aliso-wood that had not previously been used for structural purposes. Vélez claimed that "not even in botany can you be racist" since the trunk of the plant can withstand wind and rain on its foliage.



Imagery from Simón Vélez (Vélez, 37)

Structure:

The Guadua Pavilion is a ten-sided polygon that covers two-hundred square meters. The roof uses guadua bamboo as well as cement mortar tops with ceramic roof tiles that are waterproofed with a mantle. The roof is also cantilevered; seventy percent of which are overhangs at a 7.5 meter span from the ground level weighting 200 kg/m^2. There is also a mezzanine of $550m^2$ with a 10cm thick concrete slab rests on 40 columns that consist of 6 trunks of aliso-wood that are tied with iron clamps. The wood does not touch the ground since the columns rest on a steel ball with socket joints that are anchored to a concrete base. Guadua roots are used to form arches to transfer stress to the aliso-wood columns that are connected by joints of steel and bolts allowing for post-tensioning due to shrinkage.

Bamboo Structure (Villegas, 55)

Testing:

Conducted by Professor Klaus Steffens, the director since 1980 of the Institute of Experimental Statics of the University of Bremen, he designed the following three load bearing tests used to determine the bearing capacity of the pavilion in Manizales, Colombia, before it was to be built for the ZERI (Zero Emissions Research Initiate) organization at the Hannover 2000 Expo.

Firstly, the testing the load bearing capacity of the 7.3 meter cantilevers resulted to a hanging weight of more than 650kg in the middle third of the spans. The deformations observed were 7mm but structure recovered once the load was removed.

Secondly, the capacity of the second floor was tested. It was loaded with 55 gallon barrels uniformly spread over the surface and filled with water until 400 kg/m^2 was reached. A

5mm deformation was observed but recovered when the weight was removed; a large improvement of the previously estimated 25mm.

Thirdly, a simulation of wind stresses was conducted by pulling the structure in a horizontal direction with one cable in the middle section and another in the upper section. Each cable was then subject to a horizontal load of 5 tons, where a horizontal displacement of 1cm was observed.

Subsequently, Professor Steffens issued a technical assessment that helped support the application for a construction permit that was granted for the pavilion to be built in the Hanover 2000 Expo. Normal methods of testing by employing static calculus was not possible as the "materials joining parts and quality of workmanship can not be measure with sufficient reliability" (Villegas, 59). This study was complemented by Professor Joseph Lindemann who did structural calculation estimations based on the results of traction, compression and flexion tests in Germany. Guadua passes all tests and was official authorized for architectural use in Germany, which was one of the countries with the strictest construction codes in the world.

Impact:

In Columbia, where bamboo was considered "poor man's timber" since it was in abundance in many parts of the world and used to build rudimentary buildings. David Farrelly expressed this regarding heritage: "Tradition only comes truly alive when we feel it from inside, sense the bones beneath the historical expression, and discover relevant contemporary forms for ourselves" (Goldberg, 56). Vélez encouraged the acceptance of the beautiful and relatively inexpensive material as a renewable resource for future generations. Termed 'takenoko' the Japanese for 'bamboo children' Vélez and Villeages demonstrated creatively the possibilities of the structural capabilities and design elegance bamboo can achieve, changing the attitude of future generations towards bamboo. Although Vélez's buildings elevated bamboo as a respected material, both structurally and aesthetically in its ingenious systems, the combined steel and concrete structure with bamboo rhizomes and culms made the recycling of the structure by disassembly and reassembly impractical.

View of the Guadua Pavilion (Villegas 53 – 54)

Bibliographic Comments:

1. For greater variation on Bamboo botanical names, varieties, forms and cultivars, see pp 234 – 396 of Meredith.

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