BUILDING WITH BAMBOO

Darrel DeBoer, architect
1835 Pacific Ave.
Alameda CA 94501 USA
510-865-3669 FAX 510-865-7022
Darrel2@usa.net

I am an architect practicing in the western United States intrigued by the structural qualities of certain bamboos. I am working to find practical means to introduce use of these bamboos into U. S. building practices and to explore structural uses of bamboo.

Unprotected from sun and rain, a bamboo trellis will last until the adjacent clumping bamboos mature into a living trellis.

Bamboo has been documented with over 1,500 different uses. In the area of building, that includes fences, gates, trellises, and every part of a structure. Bamboo tools, utensils, and buildings are an important part of life for half the world's population. In temperate climates around the world, bamboo supply can be maintained indefinitely while maintaining erosion control, watershed integrity, soil health. What we lack is Summer rain.

Bamboo housing has been traced back to 3500 BC; it can last for several hundred years, as seen in rafters in a traditional Japanese farmhouse. Bamboo structures were popular in Central and South America for both rich and poor until several catastrophic fires in larger Colombian cities around the turn of the century relegated the use of bamboo to the poor. It is estimated that in Guayaquil, Ecuador today, over 800,000 people live in bamboo structures.

A building-permitted structure at the U of Oregon

As a building material, bamboo is special - both because it handles long spans and has such intrinsic beauty. The main reason we can – for the first time – look seriously at this plant is the joinery system developed by Simon Velez and others in Colombia

It is the process of establishing the production system appropriate to our culture and time that is most important to think through now. Gaining access to inexpensive land not usable for any other purpose, choosing appropriate species, allowing the time for maturity, understanding the aesthetics of working with cylindrical materials in a predominantly rectilinear society, learning to find exceptional working stock, and developing a design approach that takes full advantage of both the strength and beauty of the timber bamboo – these are our challenges.

BAMBOO AND SUSTAINABILITY

As an architect with an interest in maintaining my supply of building materials, I find that bamboo meets the basic criteria for continuous use. It is:

Renewable - The Phyllostachys varieties-most suitable for growing and building in the U.S. where we must deal with frost-will grow 12-15 inches a day once a grove is established. Culms (the living poles) emerge as large as they will ever be in that first six-week spurt, then spend the next three years replacing sugars and water with silica and cellulose. Structurally, they are only useful after that third year, which is about when the plant considers the culm expendable.

5" dia. P. vivax in the SF bay area. The roots extend into the lawn, excess shoots are transparently mowed

Plentiful - Our current meager U.S. supply of timber-quality bamboo can increase manifold within a decade with species selection appropriate to the microclimate, water, and nutrient availability. For now, temperate varieties such as Moso are being imported from Asia. These are well suited to being grown here.

Find uses for the much more common small diameters and easily-made splits; Bamboo in tension is at its best

Local - Bamboo concentrates a large amount of fiber in a small land area, creating that rare situation in which a single person can be both producer and consumer of a building material. A bamboo builder is not dependent upon the whims of the marketplace and can create a long-term source of material. Few other materials, besides earth, can make such claims.

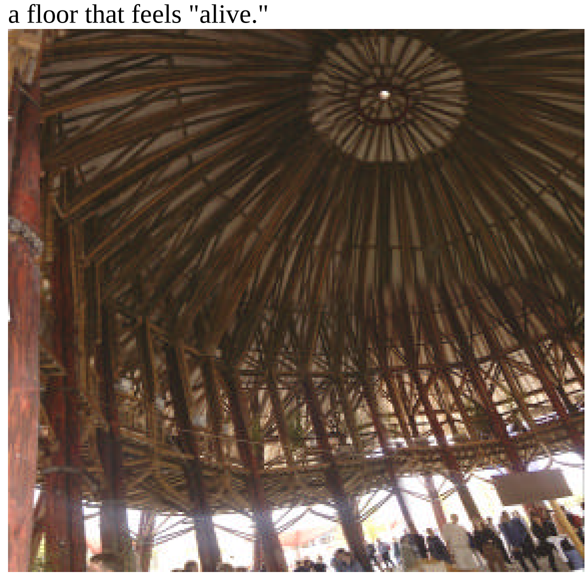
Waste-reducing - As is nature's general practice, nothing goes to waste. The leaves are high in nitrogen, making good feed for livestock. Any fallen leaf compost goes to fertilize the next generation.

Bamboo systems in Japan, Southeast Asia, and Central and South America involve the same small number of people all the way from planting through utilization. There is minimal need for infrastructure or equipment. Every part of the plant has a use, and the appropriate timing of that use not only doesn't hurt the plant, but encourages future vigor. The groves can be located to take advantage of the plant's unusual ability to quickly process nutrients left over from, for example, livestock farms, sewage treatment plants, and industrial wastewater systems. In contrast to most plants, the addition of fertilizer does not diminish the quality of bamboo poles, as the energy is stored in the rhizome for later release as next year's culms. (Liese '92) Meanwhile, those rhizomes are useful for holding topsoil and for erosion control. The plants transpire to create their own microclimate, cooling a grove as much as 10-15 degrees F., so a house surrounded by bamboo has much cheaper air conditioning.

STRUCTURAL PROPERTIES

Bamboo is an extremely strong fiber; with twice the compressive strength of concrete and roughly the same strength-to-weight ratio of steel in tension. In addition, testing (Janssen '97) has shown that the hollow tube shape gives a strength factor of 1.9 over the equivalent solid pole. The reason is that, in a beam, the only fibers doing work are in the very top (compression) and bottom (tension). The rest is dead weight.

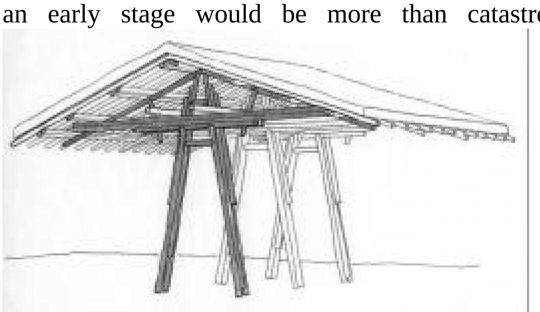
The strongest bamboo fibers have a greater shear resistance than structural woods, and they take much longer to come to ultimate failure. However, this ability of bamboo to bend without breaking makes it unsuitable for building floor structures because of its natural bounciness. In this country, there is a very low tolerance for deflection, and few here will accept a floor that feels "alive."



Through most of the world, there is no provision in the codes for bamboo construction. Experiments to gain the sixty-six foot spans and thirty foot cantilevers achieved (as shown above) by Colombian architect Simon Velez have taken place far from any inspection. Now that these exist, they stand as proof of what works, and as a model that might enable us to attempt only one-quarter of Velez' spans and still find it adequate for most of our needs. Because of the relative scarcity of timber bamboo in the U.S., one of the best uses for this giant grass is as a truss, taking advantage of both its strength and its beauty.

Garden structure for Eric Lloyd Wright with new forms of triangulation and stainless bands to resist splits

Although bamboo is a bending and forgiving material, structural redundancy is a must in truss design. It is imperative that we overbuild; a structural failure at such an early stage would be more than catastrophic.



A center-bearing truss designed by Simon Velez

Some of the bamboos in the above truss are layered three thick. It is crucial to understand which members are in tension or compression, and which points in a structure experience maximum shear and moment. Do some small-scale work with the material to really understand what feels right, then find a structural engineer who can do the calculations for you.

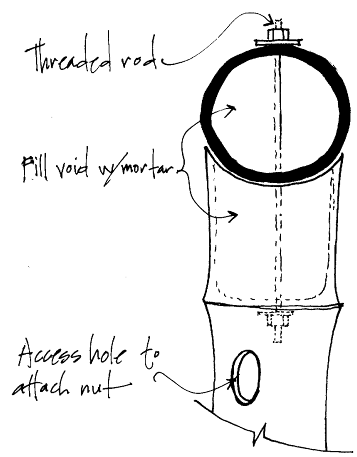
EARTHQUAKES AND WIND

There are two strategies for overcoming lateral forces in a bamboo structure. One, represented by the more recently engineered Latin American structures, relies on the shear resistance provided by mortar on both the bamboo-lathed walls and the roof. The success of this approach was demonstrated in April, 1991, when twenty houses constructed in Costa Rica under the instruction of Dr. Jules Janssen survived a 7.5 Richter earthquake. The second approach uses the flexibility of the traditional lashed, pinned, or bolted joints of both Asia and the Americas. The bolts allow for longer spans, but both proved their merits in the 1999 Colombian quake almost ten times as strong as the Loma Prieta as virtually no bamboo structures collapsed while over 75% of the rigid concrete and brick structures collapsed. Even the structures created with intuitive engineering and non-optimized joinery take great advantage of the broad elastic range of bamboo in allowing it to be pushed out of shape and then return once the load is removed.

JOINERY DESIGN

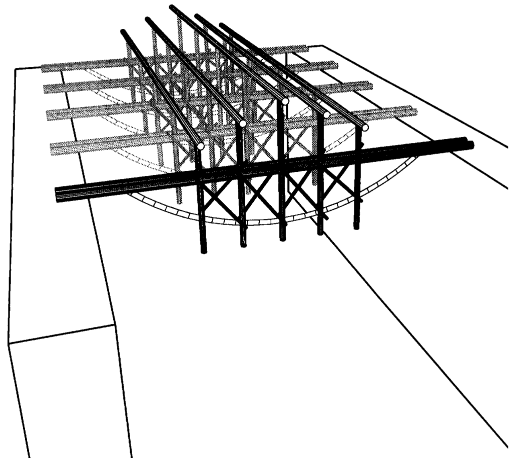
Simple, quick joinery systems based on pegging and tying have evolved to take advantage of the strong outside fibers of this hollow tube. More recent systems have been engineered to make joinery stronger and less labor-intensive. Lashed joinery has been used successfully for millennia. It allows for movement, and if natural fibers such as jute, hemp, rattan, or split bamboo are used while still green, they will tend to tighten around the joint.. Unfortunately, in most of the U.S. the seasonal moisture changes will cause the bamboo to expand and contract by as much as 6% across its diameter (Dunkelberg '85), causing a slackening of the joint; not all joints remain accessible for tightening.

Garden pavilion built in Portland with Troy Susan



FISH-MOUTH JOINT

The joint of preference has become the one developed by Simon Velez in Colombia. He relies on a bolted connection, understanding that the bolt alone concentrates too much force on the wall of the bamboo. Therefore the void between nodes is filled with a solidifying mortar. Where members of a truss come together at angles, and tension forces are anticipated, a steel strap is placed to bridge the pieces – mostly because the configuration of the strap allows that connection. Nevertheless, in all of the dozens of structures he has built, Velez says, "I have never seen the bamboo fail, only the steel straps have failed under load testing."



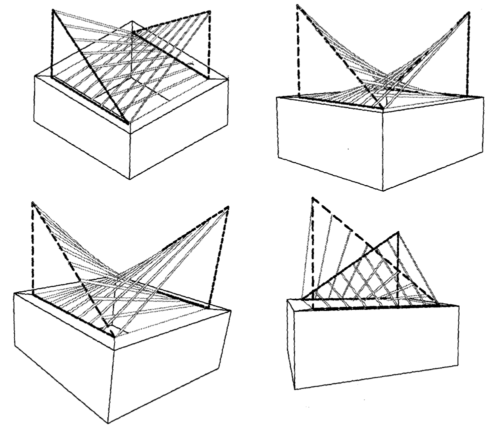
Checklist for a well-designed bamboo truss structure:
§ Good solid static analysis to distribute loads more evenly among the joints and axially along the pole
§ Slenderness ratio of less than 50 (Arce '93)
§ Bolted joints with solid-filled internodes
§ Dry poles that are still easily workable - about six weeks after harvest is ideal.
§ Harvest should only take place when sugar content in the culm is low
§ "Good hat and pair of boots" for your building - keep the poles out of the sun and dry
§ Find a way to obtain lateral strength - either through creating a shear panel consisting of a mortar-bed over lath or avoid mortar altogether and allow the structure to deflect and return
§ Refer to the engineering formulas and testing criteria developed by Jules Janssen (Janssen '97)

CODE APPROVAL

Jeffree Trudeau and David Sands, of Bamboo Technologies in Hawaii, have been working to achieve code acceptance by first building a ferrocement house with stay-in-place formwork-panels and joists that just happened to be bamboo. Then, once the inspectors were comfortable with the idea, they received an open letter from the County of Kauai Building Official which generally requires the stamp of a structural engineer or architect and special inspection (UBC Section 306.a.14). They also suggested that a prescriptive code be developed by the local design community to "provide uniformity in submittals." The first all-bamboo structures have been approved in conformity with the current code. Trudeau and Sands are currently working on a Uniform Building Code standard for bamboo.

THE CHALLENGE

While there are already a few thousand timber bamboos growing in the western and southern U.S., the whole system of growing, processing and especially understanding bamboo does not yet exist in this country.



Using straight poles to form curved surfaces

So bamboo structures can make a significant contribution to increasing local self-reliance, allowing affordable construction without reliance on highly industrialized, proprietary systems while taking some of the pressures off the forests. First, locate some untended local timber bamboo and offer to thin and fertilize it. Then, plant hundreds of new starts to plan for your future and try building something smaller than 120 square feet, which the Uniform Building Code allows without a permit.

Bibliography

§ Arce-Villalobos, Oscar, '93, Bouwstenen 24: Fundamentals of the Design of Bamboo Structures, Eindhoven University, the Hague, ISBN 90-6814-524-X
§ Dunkelberg, Klaus et al, '85, IL31: Bamboo as a Building Material, Institute for Lightweight Structures, Karl Kramer Verlag, Stuttgart, ISBN 3-7828-2031-2
§ Janssen, Jules, '95, Building With Bamboo, Intermediate Technology Publications, London, ISBN 1 85339 203 0
§ Janssen, Jules, '97, Bamboo: A Grower & Builder's Reference Manual, Hawaii Chapter, ABS
(73-4533 Kohanaiki Rd., 8b; Kailua-Kona, HI 96740)
§ Liese, Walter; Hidaldo, Oscar; Cooper, Gib; et al, '92, Bamboo and its Use - International Symposium on Industrial Use of Bamboo, International Tropical Timber Organization, Beijing
§ Velez, Simon; Marcelo Villegas et al, '96, Tropical Bamboo, Rizzoli, New York (avail. From Gib Cooper, 541-247-0835)

bus stop made in one-day workshop

Bamboo plywood bench
(all work in this article is by the author, unless noted)