U.S. Bamboo House of the Future: Standardizing Ecological Living

Lucy Wong

Bachelor of Fine Arts
Parsons: School of Design, 2001

Submitted to the Department of Architecture on May 25th, 2006 in partial fulfillment of the requirements for the degree of Master of Architecture Studies at the Massachusetts Institute of Technology, June 2006

Author: Lucy Wong
May 25, 2006

Certified by: Andrew Scott
Associate Professor of Department of Architecture
Thesis Supervisor

Accepted by: Julian Beinart
Professor of Architecture
Chairman of Departmental Committee on Graduate Students

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This thesis focuses on ecological living through the use of bamboo. It explores how the material can be used for methods of prefabricated housing design within the United States. It also uses a “kit of parts” and describes two examples that exemplify good use of bamboo. While bamboo is increasingly being used as a source of material in many applications, including elements such as flooring, decorative elements, and even semiconductors, it has not been used as a structural material in the United States, where most built projects are created using a wood frame structure. Bamboo has several advantages as a green machine that can positively influence our lives. Some of these advantages include its high strength to weight ratio which is comparable to that of steel and wood. Bamboo’s short duration allows for renewable architecture to turn over more rapidly. New technologies have overcome previous problems such as the susceptibility to termite attacks and weaknesses in joint connections.

This thesis intends to revise the idea of ecological living in the United States that integrates bamboo into housing construction. There are three main parts in this thesis: the first is to explore the aesthetics of bamboo structures. The second will take a look at the workings of joinery systems that appeal to the U.S. market. By synthesizing all my findings from the research literature, a city dwelling habitat will be designed through the use of a “kit of parts” innovation.

Thesis Supervisor: Andrew Scott
Title: Associate Professor, Department of Architecture
To Lisa, Lily, Joe, and my parents, Rosanna and San

I’d like to thank those that made my time here at MIT a truly unforgettable and rewarding experience:
LK, CV, MD, SCS, JK, AK, RT
AC, VS, BS, VV
FE, XM, OS, AF, SS, DA, SN, LS
Andrew, Shrimp, Ike, and Adele
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“Canes as thick as a man’s thigh...” Christopher Columbus, September 1502
Preface: Ecological living
Ecological living

Did you know that the first green plant growing after the bombing of Hiroshima was bamboo? Also, bamboo is similarly structured to “human genes”. The various bamboo grown around the world all have 57 internodes per shoot and extends these internodes as they grow. Thirdly, all species grown on earth, flowers and dies simultaneously. Finally, pandas consume an average of 50 pounds of bamboo per day. Bamboo has interested and facinated communities for centuries. It is my intension to heighten ecological living within the United States.

My interest in ecological living sparked my research in green and sustainable architecture using naturally occurring material. Through my research, I was exposed to the material bamboo: a renewable, replenishable, hardy, and strong constructible grass. Ecological buildings made of natural organic materials help prolong the lifespan of the living earth. Ecology studies the natural interaction between the environment and the inhabitants that use it. Therefore, one cannot live without the other.

Bamboo has not enjoyed significant popularity in the American housing industry as it has in Asia. There are two reasons for this. First, bamboo is rare in the U.S. – it is not native, only grows well in a few U.S. climates, and is surpassed by the significant and well-developed indigenous timber industry. It is not prominently grown in the U.S. for two reasons: Bamboo is not accustomed to the weather and when it is, the nurseries are overshadowed by the large timber industry in the U.S. However, this can give bamboo structured buildings uniqueness and make them stand out from wood and concrete. Bamboo that are currently growing in the United States are too small to use as structural beams and shipping bamboo here doesn’t seem to be financially beneficial at the moment. Wood, on the other hand, is mass produced in this region of the world and rarely fails to grow. Bamboo is a very useful material that has strength that is much greater than its own weight. Though originally considered a fire hazard, new technologies have been developed to address this deficiency. Bamboo is a type of weed that shoots straight up with similar internodes, therefore every piece grown can be used.
In order to succeed in using bamboo, one needs to be socially conscious of regional characteristics, especially inspiration from the culture of a particular place. Critical regionalism can give meaning to architecture by reflecting on the surroundings through local materials, the culture, and the needs of a place, including modern architectural qualities and building techniques.

Because Americans are infatuated with renovating and upgrading homes in ten to fifteen year increments, bamboo is a building material that can correlate well with this high turnover. By using sturdy low cost bamboo housing parts, architects can create a functioning habitable space, while creating a new aesthetic building technique in which inhabitants can dwell. It may be a viable building material that is competitive with, if not better, than wood. Bamboo can be used in different building techniques including prefabricated housing.

Given the usability of bamboo as a natural building material, I am proposing a housing unit constructing with bamboo with the assistance of parametric modeling tools in creating its form. My goal is to create public and private spaces that follow the various types of movement shifts within the building. The relatively cheap and organic material for this housing unit will establish an architecture that can ennoble the current and future standard of living. My goal is to make a contribution to society with my research and to further the exposure and expansion of bamboo in the temperate U.S. climate.

This thesis intends to rethink the U.S. prefabricated housing market and the integration of bamboo usage, both of which are inherently attached to negative stigmas. There are three main parts in this thesis: the first defines beauty within bamboo structures by looking at its attractiveness in the world market and researching its attractiveness to the U.S. while choosing a location that qualifies as the best location for use of this material. The second takes a look at defining working joinery systems that appeal to the U.S. market. Three different joinery techniques were designed, and the best of these has been elaborated in detail. This became the basis to the joinery system in my design.
Lastly, using these elements to guide the design, the third part presents a modern city dwelling habitat built by using the “kit of parts” approach. This “kit of part” looks into new inventive ways in combining known architectural elements. More specifically, these elements are: walls, pods, roofs and columns.
Bamboo Attraction
Why is Bamboo Attractive?

Bamboo is attractive because it is easy to produce rapidly and has the strength comparable to other materials, most notably, wood. Bamboo’s beauty can be incorporated into three categories: feasibility of the bamboo market, where it grows, and in the U.S., the question of growth due to climate and temperature to thrive.

Bamboo can be used to generate a vast number of components that can be used in almost all areas of everyday living. If the United States chose to focus on the bamboo market it could invest in growing the material in viable areas. The current bamboo market is valued at $10 billion, with China claiming half of its growth. In 2015, it is projected that China will grow up to $20 billion in bamboo sales. The United States should take the opportunity to tap into this large and growing sector. Bamboo is cost-sensitive and comparable to good solid wood sections for furniture building. In fact a bamboo composite material, which is similar to plywood, is called “plyboo” and is one of the leading new materials used in high end interior design. The United States needs are aligned with bamboo’s characteristics. One characteristic that stands out is replaceability and renovation in American living. The form of a house adapts to the lifestyle of a family throughout its lifetime in three phases: the primary, the main, and the aging.

The primary arrangement of the home structures around the living areas for young children and safety. This limits circulation and movement around the house by creating barriers against dangerous pathways. Raising a safe family gives home parameters within which to design. The main home phase deals with the development and creativity of growing children. This sets a home’s internal structure as something that is durable, ever changing, and versatile. The last phase relates to the grown children that have moved away leaving the parents with a vast space that they once shared with their offspring. The entire space could be manipulated to create larger rooms doing away with the small separations that were necessary when the children were home. These three life phases could be morphed into one home if the walls were changeable when
needed. Different configurations could be detailed to improve arrangements or add new features.

After having contacted several companies that grow bamboo, I am aware that there is an ability to foster close contacts with bamboo nurseries and establish a working relationship that could potentially be positive for future usage, testing and information.

Location

Bamboo is currently being used as a structural material in Asia and South America. It has been used as a building material in Asia for more than 1000 years. It grows and matures much faster than trees in the US such as Douglas fir (+100 years), oak (10 years), and southern yellow pine (7 years). A typical bamboo grows to approximately 100 feet or 8 stories within a few months and can reach maturity within 4 years. It has been used as a material in earthquake-prone areas such as Costa Rica and Columbia. Bamboo is strong because of two factors: the underground rhizome, which pre-develops into a bamboo shoot to become the fully matured bamboo clump. Secondly, the strong fiber lengths vary across the culm wall. A key difference between wood and bamboo growth is that wood grows by outward layering of rings while bamboo grows by stretching upward. Different types of bamboo grow in regions according to the climatic conditions such as wind and temperature.

Only a few thousand poles of construction-grade timber bamboo are currently grown in the U.S. Clearly more bamboo will be needed to make the country self sufficient with this building material. Importing structural bamboo from Asia weakens the grass with blemishes and other negative factors therefore growing and harvesting will give better value and options for long term use in the U.S.
World

There are over 6 billion people in 2000, and at the current rate world population will exceed 7 billion by 2020. With 600 million urban dwellers in Africa, Asia and Latin America living in “life and health threatening homes”, developing a user friendly home is critical. Bamboo has a strong potential to fill the housing void. This research aims to keep expanding the idea that bamboo is a useful building material for homes in the United States, and can potentially solve the problem for international homes that are in critical need of shelter at the same time.

There are around 1200 documented species of bamboo existing around the world. Bamboo is currently growing in these countries: Japan, Korea, Southeast Australia, New Zealand, Southeast America, Hawaii, South Brazil, Central-South Chile, Northeast Spain, South France, North Algeria, North Iran, South Africa, Italy, China, Columbia, and Philippines.

Around one billion people on earth live in bamboo homes. In Bangladesh, 73% of the population lives in bamboo houses. The material could be used in different architectural features such as window frames, rafters, room separators, ceilings, as well as necessary structural components such as pillars, walls, and roofs.

United States

Out of the 1200 species of bamboo, 373 thrive in the U.S. There are 91 bamboo nurseries and product suppliers (see appendix) nationwide. Bamboo is growing in locations across the United States such as: Washington, California, South Carolina, Indiana, and Georgia.

In the United States, there are several regions that foster the climate needed in con-
structing with structural raw bamboo. The cut bamboo is chemically treated for infestation and the raw material could be used immediately. Composites are also secondary features of this primary treatment and can be used in all regions within the U.S. The zones for using raw bamboo are in zones 10 and 11 which are located in certain parts of Florida and most of Hawaii. The transformation in the usage of bamboo for construction could potentially create a variety of community structures in American suburbs.

Historically speaking, 5 million acres of cane-brake bamboo naturally grew in the Southeast region. Unfortunately with wood forestation, the grass was uprooted and replaced. However with rising timber prices the U.S. sees great potential in bringing back this native plant, assuming sufficient demand. Testing and researching began as early as the 1950’s at Clemson University in South Carolina.

Hawaii

Hawaii was the chosen area for the basis of my research because of its climate and economy. First, the climatic zone permits bamboo to be used in its original raw form. The second is due to Hawaii’s current economic state. As their sugar cane fields have caused soil erosion and are about to be of no use, Hawaii is searching for a renewable material that could help bolster the economy as well as its land. For example, the Philippines were in a similar state in 1985 when their sugar plantation fields were replaced with constructible bamboo. Replacing the sugar cane with bamboo brings several benefits. First, bamboo absorbs flood water. It also replenishes forestation, and creates new bio diversity which in turn, bolsters economy when used as a source of building material.

Hawaii has been a part of the expanding U.S. territory since 1898 and has a current population of 1.3 million. Floating from coffee, macadamia nuts, pineapples, and sug-
Hawaii is currently seeking a new product to boost its economy. The topography of the land varies considerably with valleys, bases and mountainous regions which residents have inhabited throughout the years. With outdoor events and tourist attractions gaining popularity in the past decade, bamboo has the potential to be used in a variety of different housing projects.
History of Bamboo
Material Comparison

Since this research does not deal with the structural properties of bamboo in detail, some qualities that are important will be mentioned, and will be relevant in the later parts of the design section. The interested reader is referred to Jules Janssen's book, “Building with Bamboo” and Klaus Dunkelberg’s “Bamboo as a Building Material” both of which explores bamboo’s structural capabilities and different applications. The books also include detailed joint connections and cladding techniques. The research that I am about to explain is the works of Jules Janssen, an engineer in the Netherlands who has worked on bamboo research since 1974. He, along with other prominent architects and engineers in the field, have been key players in pushing forth the possibilities of bamboo usage in other parts of the world besides certain Asian and South American countries. In both places, bamboo construction could be improved. Bamboo is used in housing because of the ease in obtaining the material in these countries.

Bamboo compared to other materials

Bamboo is slightly stronger in tension than iron and has half of the tensile strength of steel. It also has twice the compressive strength as concrete and similar in compression strength as aluminum. Bamboo has a strength to weight ratio greater than wood.

One notices that bamboo is just as good as or even slightly better than materials offered in the current U.S. market. Bamboo has strong linear fibers which have twice the compressive strength of concrete and almost the same strength to weight ratio as steel in tension. The fibers are twice as strong as wood due to its underground rhizomes and its hollow cylindrical shape. In terms of energy efficiency, processing bamboo requires only an eighth of the energy to process concrete and a third of the energy to process wood. Surprisingly, when comparing energy processing to steel, bamboo only uses 1/50 of the amount of steel.

If compared to wood, bamboo is much lighter due to its hollow nature. Housing
construction and rebar use after chemicalization in reinforced concrete beams use raw bamboo. With its composite, manufactured usage, “Plyboo” is much stronger than standard plywood which can be used for everything plywood is used for, that is, wall paneling and floor tiles.

Buildings with materials like steel and wood use structure to help guide the design. To comply with rigidity requirements, a rigid wall, a truss roof structure, and a well engineered joinery are used to balance the deflection that dominates the construction parameters. Wood flexes to a lesser degree than bamboo but has established building codes to keep it rigid for use. Two ways to use bamboo in taking advantage of its flexibility in a positive light are bridge and earthquake design. Bridges flex as load is distributed throughout the structure thereby creating less stress on the joinery, so bamboo and its joints are a good source of material for bridges. The earthquake and hurricane resistance of bamboo stems from the fact which in combination with its low mass makes bamboo a favorable material in disaster prone regions. For example the 30 homes located near the epicenter of a 7.6 magnitude rector scale earthquake in Costa Rica survived the disaster without any major damage. Bamboo also does not have rays, radiating curves in wood, which are mechanically weak therefore bamboo material is better in shear than timber material\(^4\). Bamboo has the ability to withstand lateral load through the use of sheeting materials such as mortar and polycarbonates or through triangulation.

**Timber vs. Bamboo**

By making a comparison between timber and bamboo, both being used in raw form and in engineered composite form, one can see the benefits of investing in bamboo forestry.

For every one cubic meter of bamboo = two cubic meters of cut lumber is used = fifteen cubic meters of pressure treated wood used
If one substitute split or solid bamboo for wood = thousands of cubic meters of timber saved

Costa Rica, has been forging with using structural bamboo as 1000 bamboo houses are built per year. With a bamboo plot of 20m x 20m, two 8m x 8m homes could be built after the first 5 years. Each year after that would yield 1 home on the same plot. If these houses had been built with timber, 600 ha of natural forest would have been necessary. It also generates a higher oxygen rate, at 35%, than any other plant.

Competitors Entering the U.S. market

How long did it take other materials to enter the U.S. market? I have looked into four frequently used materials as comparisons.

<table>
<thead>
<tr>
<th>Material</th>
<th>Year of Entry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoclave concrete</td>
<td>1914, Sweden</td>
<td>Aluminum powder to cement + lime + water + finely ground sand</td>
</tr>
<tr>
<td></td>
<td>successful entry April 1996</td>
<td></td>
</tr>
<tr>
<td>Plywood</td>
<td>1600's by French and English</td>
<td>Cementing + ply grain running crosswise or diverse</td>
</tr>
<tr>
<td></td>
<td>successful entry 1907</td>
<td></td>
</tr>
<tr>
<td>Straw bale</td>
<td>a long time</td>
<td>Straw and mud</td>
</tr>
<tr>
<td></td>
<td>successful entry 1896</td>
<td></td>
</tr>
<tr>
<td>Rammed Earth</td>
<td>820BC</td>
<td>Material: a combination of soil, water, and stabilizer</td>
</tr>
<tr>
<td></td>
<td>successful entry 1930</td>
<td></td>
</tr>
</tbody>
</table>

History of Bamboo

Bamboo has been implemented in about 1500 different ways since 3500BC. It is fast-growing and provides for every necessity in life, be it building, food, or amenities. Some
of the uses of bamboo are landscaping, construction, bridges, fencing, trellis, interior architecture such as vent screens, separation spaces, staircases, chairs, containers for food, trough for transporting water, food, paper, furniture, mats, baskets, medicines, aircraft fuselage, seven-stories tall hillside houses, and lots more. In the western world, bamboo was a major factor in lighting homes as it was a part of the first electric light bulb invented by Thomas Edison. Bamboo is also used as charcoal which removes odor, purifies water, preserves food and acts as a dehumidifier. Bamboo is used for everyday living in Thailand, Indonesia, and the Pacific Islands.

Bamboo can only be harvested in a certain seasons to avoid insect and fungal attacks in the western U.S. It usually does not matter whether it is a running bamboo, which spreads like a weed and sits inches from the topsoil, or a clumping bamboo, which groups itself and tends to bury its roots down the same distance as its height.

Simply, bamboo grows as a loop around the world; it can thrive in almost all parts of the world between 46N to 47S latitudes. Yet the largest component of structural bamboo can only be used in tropical and temperate regions. The nature of the material will not allow it to weather well: In wet climates, the bamboo rots. In dry climates, the bamboo cracks quickly. Replacement will be needed at a faster pace thereby creating a higher cost for material and labor. The most widely used bamboo for structural components is the species, Guadua Augustofia. This 6' diameter bamboo is widely used in South America.

Bamboo is a renewable and sustainable structural material. Bamboo grows quickly. The “culms”, which are the stem portions between the internodes, tend to grow to be 120 feet tall or 10 stories high, depending on the type of bamboo, in only four years. A return of investments happens every year after the initial four years. One clump assures that fifteen kilometers of usable pole are grown in its lifetime. Most bamboo grasses flower every thirty years and stay sedentary for five years before they start to grow again. Bamboo is rather straight, which makes joining typically simple. With different sizes within a culm, various usages could come from one cane.
Natural clumping occurs in these strong linear bamboo nurseries.

Image: Simon Velez, Grow Your Own House. pg. 17

stronger if grown on a slope side than in a valley and is even more solid if it is grown in poor dry soils than in rich soils. This is good for Hawaii's sugar crop replacement.

Construction grade bamboo consists of a culm, whose base circumference of which is more than 58.2 cm. Some of these are: Bambusa (blugena) grown in the Philippines, Ohe Kahiki in Tahiti, Bambusa vulgaris in Hawaii, Guadua angustifolia bicor in Latin America. Others are Guadua de castilla, Onion Guadua, Dendrocalamus giganteus, and Bambusa oldhamii. The height of a bamboo can be found by measuring the base of the circumference x 58.2. If a culm is less than 5in, it is considered a low quality piece and can not be used for construction.

History of Bamboo construction

Around 9000 years ago, the Americas, most parts of Asia, and certain areas of Africa began using bamboo. The Incan Empire had developed a basic platform-construction method still used today. 3000 years ago, the same group of civilizations had started to use bamboo in engineering. Some of these uses are: suspension bridges and pontoon bridges, tension bridges, gabions (basket of bamboo secured at the banks) to dam rivers and streams, large 100 feet communal houses, corbelling ten meters technology, scaffolding for highways construction tied with 1 mm strips, traditional tea houses and vernacular architecture in China, Hong Kong, Southeast Asia especially in Indonesian Celebes Island, Japan, Borneo, the Naga Hills of India, Central and South America.

The following are examples of countries using bamboo as a structural material: India where they curved roofs (Chorals), the French built a beautiful ringed buildings (although they were destroyed by insects), bamboo domes made of split bamboo in New Guinea, bamboo “boards” with plastered in Colombia, and the Costa Rican platform framing program provided by the government. In the U.S., permanent structures have used bamboo as rafters and purlins in wood posts and pine log beams for the ceiling.

Currently one way bamboo could be used to create different shapes is by forcing young
culms to grow through a tube of another shape which is slightly smaller than the Culm’s natural diameter. This constricts the growth to the tube shape. The tube is then moved to a new location as the Culm grows taller every few day. As Hildalgo notes, “any type of construction member can deform to make one curved laminated beam costing $25,000 but to grow the equivalent in bamboo would cost only $100.” 17

History of Bamboo in the U.S.

In 1890, the U.S. Department of Agriculture imported farmable bamboo from Asia mainly to be used as a food and fiber crop. The project lasted for almost 9 years, but failed miserably as it did not infiltrate the market as intended. Despite the lack of commercial viability, it was successful growing bamboo in temperate climatic areas such as parts of Puerto Rico, Georgia and California. Testing and researching bamboo structures were restarted in 1950 at Clemson University in South Carolina.

In the following years, bamboo became a fixture in building constructions elsewhere around the world. Hawaii with its negative sugar production was in a need of for a new crop and was heavily looking at bamboo as the next source for economic revival for the state. In 1995, Bamboo Technologies along with their partner in Seattle built the first house with structural “Guadua” bamboo in Maui, Hawaii. The following year, the first building that was built under some of the other western building codes was erected. At that time, it was clear that a building code was needed to use bamboo in mass production. Therefore submission to the ICC was initiated. In 2001, the first two parts of the building code was completed and in 2002, the second half of the building codes was submitted. The year of 2004 marks a new era for bamboo in the United States. Bamboo Technology was approved to use bamboo by the ICC Evaluation Services to have bamboo buildings being built in Hawaii. This celebration was received by the public with the anticipation to submit their designs to the 2006 International Bamboo Building Design Competition in December 2006. 18

The U.S. is currently experimenting with using plastics, glues, and metal space-frame
connectors. The most popular bamboo grown here is the decorative Golden Bamboo and the Black Bamboo, which are both less than 1” in diameter.

**Entry barriers in using Bamboo in the U.S.**

There are several entry barriers in using bamboo some of which are current pricing, availability, environmental concerns, vertical material integration, and pioneers in research.

Bamboo is currently a rare building material with the availability as a construction material costing anywhere between $30 and 50 per pole. External shipping makes it ten times more expensive, if it is shipped from overseas, like Hawaii. Composite plyboo is not any different coming in at $200 with student pricing for a 4’ x 8’ sheet as opposed to a plywood sheet that costs no more than $60. By processing bamboo, the overall value to the product is high and comparable to other composite materials such as plywood.

One major concern is its environmental impact. Bamboo is a grass that spreads like weed, which could destroy existing habitats. It is also very vulnerable to different types of weather; the more tropical the quicker is the deterioration process. For example, in tropical rainforests, non-treated poles live for only four years. If it is not harvested at the right time, the culms become vulnerable to fungi and insects. Another concern is the toxicity of the harvestation treatment of bamboo. Benign solutions should be used such as smoke processing or water based resins such as melamine fortified urea formaldehyde. Resin, soy based, or aliphatic carpenter glue could also be used.

Because of the lack of thorough building codes, there are currently very few bamboo construction establishments in the U.S. There is currently a lack of information on a universally naming typology specific to each species as well as testing methodology, international code standards, and the joinery process investigation.
Methods

It takes about four months to process bamboo. The raw plant is treated with chemicals to control termites, insects, and rot. It needs to dry in a cool dark location without splitting the hard outer layer for four months. This allows the culms to last for more than ninety years.

There are various ways to cure bamboo but one simple way to do so is by keeping the cut culms vertically in a stone pit for a month. Afterwards, they are soaked in water for four weeks and then saturated in a 0.3 solution of caustic soda. Another way to keep bamboo moist and insects free is to coat the culm with mortar or using the water tank method. Other non toxic ways of preservation is to employ pending, boiling, smoking or clump-curing. In Japan have naturally cured roofs by smoking as they cooked food in the home. This smoking process processes the home to be erected for a hundred years. Bamboo should not be kiln dried as bamboos moisture leaves from the ends of the pole. Another process would be to de-wax the exterior and strengthen by curing. Finished cured culms are laid horizontally and out of sunlight for storage. These processing methods can be found in Jules Janssen’s book.

Case Studies

Case Study #1 Costa Rica

In the 1980s, Costa Rica needed to develop housing solutions using local raw materials due to the destruction of their timber supply. Rural areas needed a local resource for housing to stop residents from migrating into the cities. The Costa Rica Proyecto Nacional De Bambu (National Bamboo Project) introduced bamboo to the country and planted 200 hectares (494 acres) of Guadua over an eight-year period. Structural bamboo with mortar homes were built for only $7000 each. Those that were built in Limon withstood the 1992 earthquake while the traditional wood framed homes beside
them collapsed.

Costa Rica is now building 10% of their homes with bamboo and the goal is to reach 100% in the furniture industry.

**Case Study #2: Colombia**

Manizales, a coffee growing region, has many public buildings as well as private residential complexes constructed of bamboo. These five story platform framed homes with reinforcing diagonals bracings were built on steep hillsides. Because of the difficulty of leveling bamboo, lumber was used for beams and joists. In the 1930 earthquake, the bamboo architecture survived while others didn’t.

At another coffee park in Pijao, The Watchtower designed by Simon Velez, rose up to eighteen meters tall, and seven meters wide and still stood after a horrific earthquake.

**Case study #3: Philippines**

The Philippines entered the world market by trading sugar cane in 1980 and by late 1985, the country suffered from the drastic lowering of trade prices. The consequences were disastrous: the country was in widespread poverty and most of the population was malnourished due to the growth of sugar cane. Sugar cane deforested vast amounts of land, created soil erosion, and bio diversity was lost. Bamboo which thrives naturally in the region was carefully being studied at that time. Harvesting techniques, growth patterns and new bamboo species were introduced and documented in the country in 1987. This has created a surge of improvements for the country. The Philippines are currently a top supplier of bamboo furniture and have doubled their investment in just ten years.
Bamboo
Architects as Client
United States

Many of the research currently underway in the U.S. are provided through University funding or privately own businesses. Two of these stand out: Michael McDonough and Bamboo Technologies.

As an architect and consultant, Michael McDonough, had foreseen the benefits bamboo would allow for product design to change positively. He created a set of lightweight furniture pieces in 1988 which exemplifies some bamboo techniques of joinery. As Michael states, “we (The Environmental Bamboo Foundation) could promote bamboo through use rather than through proselytizing.” (footnote: http://www.umb.edu/alumni/magazine/1999/spring1999/about_alumni/mcdonough.html)

In Hawaii, Bamboo Technologies, a company headed by Jeffrey Trudeau and David Sands who also has partners in Seattle, is currently working to bring bamboo into American culture. They have started to bring bamboo into certain communities that are willing to try the material and have begun the necessary paper work to form a building code around bamboo. Other than the usage of these in five permanent structures, mostly in Maui, bamboo construction has been slow. Since 1995, Bamboo Technologies has submitted documentations for a working permit to build. In 2004, they have successfully achieved certification for a building code deeming the material as a structural material ready to be used as building structure. This hurdle is the beginning of a bright opportunity for bamboo to be proven nationally.

Bamboo is also becoming a staple as a composite material for use in decorating movie environments. “Aeon Flux” and “The Time Machine” (1999) used plyboo as the basis for its set design. In “Aeon Flux”, most of the stage sets were structured with bamboo and comprised of a plaster overlay. “The Time Machine” features a futuristic rendition of a bamboo house of the future.
**International**

Simon Velez, a Colombian who uses bunched culms when creating columns, also created the bolt and concrete joint system. These concrete injected bamboo poles were experimented in several built projects where he was able to cantilever the roof overhangs to approximately 7 meters (37 feet). This success led him to work on larger bamboo structures, such as the music hall and an expansive roof structure sheltering a gathering space. His most notable architecture was the Zeri Pavilion.

The 2000 Hanover Expo Zeri Pavilion was the turning point for recognizing that bamboo usage could be used in the developed and modern parts of the world. As the project was underway, hindrances were alarming but he continued to complete his building. A one to one scale model was built in Columbia before construction for the approved design was erected in Germany. This project paved an opening for engineers and architects. Velez proved that modern techniques and materials are able to work with this grass.

Marcelo Villegas, who work with Simon Velez on various projects, also resides in South America. Along with Velez, Marcelo built a village near a coffee plantation which includes a 60' tower constructed of bamboo. In January 1999, the tower which was at the epicenter of an earthquake, was put to the test. Devastation of concrete and brick buildings destroyed the city. Miraculously, the bamboo tower withstood the vibration. Those bamboo homes that were destroyed were built with untreated poles.

Renzo Piano has experimented with joints which combines light metal elements with bamboo. Kengo Kuma and other Asian architects, especially our Department Head, Yung-Ho Chang, was able to create a home using an ecological product. Bamboo infiltrates the room, acting as wall, space divider, and flooring.

Oscar Hidalgo, a bamboo specialist has experimented with deforming bamboo with preformed wood to create arcs and curvatures.
Jules Janssen, the mastermind behind the technical study of bamboo, owns a personal bamboo testing facility at home. As he has assisted numerous architects on bamboo projects, bamboo has become a steady material used today, most prominently, as product design, such as furniture.

Shigeru Ban and Frei Otto teamed up together for another 2000 Hanover Expedition building. The architect and engineer team created a grided organic structure that spans using recycled paper tubes as load bearing walls. Paper tubes were used because of its consistent size, shape, and weight as oppose to bamboo where each piece is uniquely shaped. Shiguru Ban created waterproofing for these paper tubes by placing material between each structure. This was also the location where another material was placed for fire resistance.
Entry strategies into the US
Entry strategy into the U.S.

It is important to find ways to help bamboo enter the U.S. market. I will define five components necessary for bamboo to adequately become accepted in the future of the U.S. They are to increase incentives to bamboo nurseries, preparing detailed marketing plans, building relationships and expanding networking potentials with clients and peers, establishing a physical presence in the material market, and creating a universal building code for the United States.

As housing costs are on the rise in the U.S. market, builders have to wait longer to spending for housing renovation. As most of the payment goes to the purchase of the home, renovations become static for some time before the family could afford to repair the home. This benefits bamboo nurseries because the material allows for consumer to purchase parts at a relatively cheap price. Bamboo is also ideal as a “one stop shop”. Bamboo can be used in all stages of its growth: at less than 30 days, it can be eaten. From 6-9 months, it can be used for product design such as basket weaving. From 2-3 years, bamboo boards, laminations or curvatures can be manipulated, and from 3-6 years, these bamboo poles are harvested for construction. Finally, after 6-12 years, the bamboo pole gradually loses its strength and could be used as decorative backyard features.

There are several key challenges in entering the U.S. market. On the supply side of the approach, it is necessary to create incentives for forestry growth. A few remedies are needed to liberalize the foreign exchange market or to institute a different tax measure, that is, to lift tariff restraints for the first four years of culm growth. Other ways include introducing financial packages for nurseries and increasing community controlled forests. Some ways the government could assist are to privatize capital flow and seek philanthropic assistance or to increase domestic demand for agriculture and forestation which could influence the global market. Finally, allowing bamboo nursery production owners to voice their concerns could greatly benefit the industrial restructuring.
Bamboo associations should prepare a detailed marketing plan to target their clients. Some of the ways include advertising in trade publications and websites such as: IN-BAR, CIFOR, and American Bamboo Society. They should encourage participation in industry conferences to bolster U.S. relationships with other countries. Promoting research within the universities could spawn new technology using bamboo as modern building material. Some of these academic universities that are currently doing research on bamboo are: Chinese Academy of Forestry; University of Sao Paulo (Brazil), Mulawaran University (Indonesia); Programa Manejo de Bosques de la Amazonia Boliviana (Bolivia); University of Zimbabwe, University of Hawaii, Rhode Island School of Design (U.S), Eindhoven University of Technology (Netherlands). Bamboo use for shelter by upper class society could open doors for widespread acceptance with use from the middle class followings.

Architects must build a network of relationships to facilitate a successful U.S. entry. Strategies include funding partnerships of architecture and construction firms to produce more research on the material, generating consultants and researchers to create innovative solutions for future products, and leveraging the supply contacts so that all companies will forge strongly into the bamboo market together. Learning from precedents such as boat building chemical processing facilities could help further development as boat building has already started to make positive strides in waterproofing, fireproofing their products. Creating bamboo home system that uses prefabricated wall panels assembled onsite from the floor up will allow homeowners to build their own homes through sweat equity. Next, architects must further the building code system with Hawaii to create a universal building code for the U.S. Lastly, buildings by architects and engineers need to have a network of contacts to promote the benefits of the material and to showcase cutting edge examples of energy efficient dwellings which could allow international acceptance to modern bamboo usage.

The U.S. needs to establish a physical presence in this material’s market in the future because currently it is still difficult as bamboo is rare and expensive. There are only
a few thousand poles harvested each year in the U.S. as opposed to other regions of the world. The poor man's material stigma is difficult to break in the housing world and this can still be seen in countries that have a vernacular history of building. An example of cultural acceptance is India. The hierarchy there consists of the highest castes using stone masonry, the middle castes using wood, and lowest castes are the ones that use bamboo.

Creating universal building codes for structural construction grade bamboo is a fundamental ingredient for long-term success. This assumption sets the premise and uniform national and regional performance standard and should be enforced in creating a standardized mass produced housing unit. This trickle down effect will ultimately entice contractors and builders to get into the business thereby spurring investment in factories by private companies and the government. Once there is high level capital funding for factories, training to increase the depth of knowledge and talent will take place. This process will ultimately become the model design that could be fit into a U.S. processing plant lifestyle and open different possibilities for the future of U.S. housing.

Bamboo architects and engineers have already accomplished several important steps to facilitate bamboo entry into the U.S. Bamboo constructed housing is already being produced in Hawaii. Composite laminated bamboo is on the surge to replace laminated wood as it gives a 25% profit return per day. Training the culms to form different shapes are already being experiment by architects such as Oscar Hildalgo. With this, it is time to standardize, prefabricate, and mass produce building elements with aesthetic designs for different rural housing typologies.
Joints
Joints

lash

pins

bolts
Joints

Along the thoughts similar to other architects such as Shoïi Yoh and Renzo Piano, joinery systems will be a main problem in the acceptance of bamboo especially in the United States. For years, bamboo joinery used intricate lashing techniques. The most readily used joinery system can be seen in scaffolding connections throughout Asia. Jules Janessen created a simple peg connection that would allow for square pieces to fit together with round pieces. This carved joint connection would be used freely. The system of prefabrication and mass production will be the premises of my joint part of the research. This will then inform the kit of parts that will be used to create the design.

In most countries, bamboo are connected with straps as well as other latched devices such as bamboo strips or metal. These connections will not last very long therefore it will compromise the structure greatly by reducing the integrity of the built object. It is usually at these locations that the building fails. It also creates a vision of instability. Taking inspiration of joinery techniques from other materials, new bamboo joinery systems can be realized with further testing. Researching connection joints with other materials such as wood and steel, allowed me to create the underlying method for my joinery system.

The primary failure occurs at the lash, pin, or bolt joints are where the bamboo shrinks diametrically. Therefore tied connections will not be used in these proposed joints. An example is when bamboo replaces rebar in concrete. The structure usually retains much of the moisture during the drying process therefore the connection fails. Structure failing in hurricanes also occurs primarily at building fasteners. Wind can uplift the roof and place dangerous lateral forces on a structure. Although natural fibers (jute, hemp, rattan, or split bamboo) can tighten around the joints, it really depends on seasonal changes where the moisture content can causes a 6% diameter flex in expansion and contraction which is the root of joint failure.
Joints

mold joint

spider joint

diagrid joint
Joint:

One method of joinery is the joint and the glass wall in-fill which sits on the same datum used similarly in wood connections. The negative realization of this joint is that if any frame is broken or shattered, replacement of the joint will create a weak point in the diagrid structure thereby making the building weaker during replacement. This is also the case when the bamboo itself needs replacement. This joint is similar to latch connections used by bamboo joints today.

The second joint I experimented with was a spider joint which is typical of glass wall connections. This joint takes the form of various shapes, to form the external building skin. Each nodal joint would comprise of two bamboo tubes bypassing each other creating a linear path so that the strength of each diagonal tube will continue to the piece above. Each node will then split off into the corner arms which connects the rectilinear glass pieces 6 inches away from the cross braced frame. This however can be rethought through because loads need to come to a single point for compression to transfer correctly. Also, the size of the joint is unnecessarily large due to the inert structural character of its shape. The node only needs to have a small connection.

The last joint I looked at was to take a steel plated joint system, such as the one used in the Swiss Re. The Foster building comprised of steel tubes converging into a single diagrid plated steel joint. Diagrids are strong facade structures that self support a building without the use of columns to allow for a free plan. As I was designing the joint, the uniqueness was its ability to slide together and create a strong connection without any glue. By creating fourteen parts, eight of which are unique pieces, the joint can combine bamboo tube of any shape and size. The joint can also flexed to ones desired size. By only interchanging one piece of the joint, three other building systems could be created.
wall joint

wall joint 1:1 scale

corner joint

corner joint

wall joint: assembling fourteen pieces
The two joint systems described below are for two different locations, a permanent and a flexible joints. They could be used singularly or both within the house. Each joint flexure will be used by specific connection regions pertaining to their usage. The flexible joint can be foreseen in wall structure while the permanent joint is used as joint connections from the column to the roof junctures. Each of these joints can form specific groupings that can be applied to construction methods.

Flexible

The first is a modifiable flexible joint. This joint allows for the structure to modulate till the specified location has been found. When the diagrid wall finds this point, the flexible joint retains its shape. The parts are fitted together to create solidity. This joint comprises of fourteen different parts, each one necessary to make the joint work. What’s modifiable in this joint is the possibility of interchanging the parts to create a different usable joint. That is, to use fourteen original pieces in creating a wall joint. The intermediate piece will become the juncture between structure and wall material. If just one piece of the fourteen piece kit was to be replaced, the new joint could potentially be used for other joining techniques such as a wall corner details and a wall-to-ceiling corner details. Each part will consist of solid fiberglass plastic pieces which are lightweight and easy to assemble. If the sheering wall shatters, replacing will be non trivial as the joints are removable. Here, the forces are transferred to the other joints in the periferre.
Pouring the male joint

detail connection of male and female joint

bamboo connections with male and female resin joint
Permanent

The second joint is one that can be used in almost all parts of the home. The joint consists of a male and female piece that works together to create the permanent joint. These parts are molded directly onto the raw bamboo and are pre-fixed before transporting them to the site. By prefabricating these pieces, this technique can easily assemble with skilled technicians in the U.S. Other necessary components that are useful for the builders, but could be purchased from Home Depot, will be directions in mixing the resin for the mold.

The molds to both the male and female parts are created differently. Each bamboo will be sanded at the end for the male and the middle for the female parts. For the male joint, the mold will be poured with resin and the bamboo placed into the wet resin till dry. The mold is then lifted after drying. The sequence is continued. The process is different for the female mold. The female joint places the mold directly on the bamboo at the specified location, enclosing it by two pieces. The joint sits tightly at the seams. The resin is poured into the mold and dried. Both molds are reusable, easy to clean, and easily accessible. There are two ways to obtain the molds. One, the molds can be purchased in a hardware store, such as Home Depot. Each joint will be fitted with a bamboo piece. The second way these molds could be marketed is by purchasing the mold and poured by skilled builders who could shape, define, and morphed the bamboo to the shape desired.

After the shapes have been molded onto the bamboo, the pieces are snapped together to form a continuous joint. Although the pieces are linked together, the joint is still flexible enough for movement so that one could still find the desired angle. Once the angle is formed, the location of the joints will be static and the compound mixture to bind the resin connection will be poured. After settlement, the interlocking joints are stiff and can not be manipulated or changed. If the bamboo cracks, replacement to both the bamboo and the joint will be necessary.
Kit of Parts
Kit of Parts

column

exterior roof

exterior wall

concrete

inner wall

2nd layer external wall

interior roof

pod sitting on wall

glass & plastic infill
Kit of Parts

The kit of parts invention allows for flexible housing construction opportunities whereby prefabricated home units could be available using bamboo. With a central kitchen, bedroom, and bathroom unit, one could configure the arrangement in a few years time as the wall size frames and apertures could change frequently. This kit of parts takes the designing of basic modular elements and standardizing the necessary components: the walls, the rooms, the roof and the column.

The “kit of parts” series is the basis of the designed bamboo home using techniques most adequate in using bamboo as construction material. These use bamboo as raw material and its composites as secondary material. Each piece of the kit can potentially be used on its own or with a pair. The maximum variation is to use all four components together.
Kit of Parts

**Wall**

The wall is a unit which functions as a secondary structure to the column and becomes the organizing framework for the internal structure of the house. Its placement works in conjunction with the pods. The flexible joint will connect the bamboo lattice together in forming the wall unit. These nodes vary depending on the aperture the screens are ordered by the owner. The resulting form follows the elements when creating the barrier. These elements are wind and acoustics, while allowing shade and view to filter through.

The wall is flexible because of its joint configurations. The wall is malleable to form different shapes, either square or organic. The wall becomes the anchor for the podular rooms where structural walls are used externally and internally. The grided structure is large enough to allow a 6' person to walk through with adequate clearance. Each wall will be in-filled with a translucent or transparent material which overlays and attaches directly to the joint to allow visibility between the interior and exterior. These translucent curtain walls made of polycarbonate, PVC tarpaulin, frosted glass or hollow sheets are removable to allow elements between public and private to intersect.
Pods

The Pods are preassembled on an off-site location. This is manufactured in the appropriate size, fitted with the necessary electrical functions, and can be used immediately once brought on-site. Each pod is specifically dimensioned with prefabricated furniture in place. Structurally, these pods are supported by the diagrid wall units. Each wall unit layers appropriately to take the load of the pods. These walls surround the pods create circulation by becoming the stair railing and wall supports and becomes defining features exemplifying the pods.

The pods are climate controlled to allow for comfortability within the home. They define the major circulations not above the open floor plan. The walls weave within the floor plan to create the internal structure and external wall system. There are three different pods made of plyboo. Each unit is dimensioned with unique qualities: the bedroom (10' x 10') consists of operable windows that pivots down to create a balcony, the bathroom (8' x 8') has a shared sink and shower control, and the kitchen (10' x 10') sitting on the lowest plane, is fitted with electrical wires and plumbing, which are masked within a hollow bamboo, that ventilates by pushing the cooking smoke down under the home and out from below.
Roof

The roof is an exoskeleton of the internal column structure. It is the organizing element of enclosure. Rain is directed away from the building by its pitched roofs. This is counterbalanced by small apertures within the mid section of the roof. It is here that elements are seamlessly brought into the house, similar to the courtyard space of a traditional Japanese home, where a reflective garden resides.

As the roof is where an area of high wind pressure and high rainfall, the roof structure consists of two inverted roof planes. The outer roof directs water out and light into the space. The secondary roof structure allows for air circulation as well as guides the rain water to the green garden below. The two roofs are braced together with a compression strut that sits directly on the column lines. The trussed bamboo roof is designed for both aesthetic and structural support.
Column

The columns are bunched tied as specific load specification are requested. As with Simon Velez’s Zeri Pavilion, bunching bamboo as a column unit allows for dimensional support. Bending would occur if brace frames are unattended to. But by focusing on the slight bend of the column to the direction in which the bending would occur would displace the transfer down into the bamboo. This column will be supported by a cable acting as a wind stabilizer. This cable is fitted with an adjustability turn buckle in the center for sagging during construction.

The columns are arranged in a grided configuration and can be positioned in a variety of different ways. The roof will reflect the level changes. If the home sits below ground, a wide expansive roof is created for a low hovering profile. On a flat plane, the home consists of a proportioned roof and frame. And finally as the house sits on an inclined plane, the roof and wall acts as one unit forming the structure that braces the building. Therefore, the expansion of the home depends on the column area and not the lot size.
Case Study

3rd level = 1 bedroom
2nd level = 1 bathroom
below grade = 1 kitchen

long section

plan

scale 1/32" = 1'-0"
#1: Valley House

The valley house sits slightly below grade level. It houses a single family comprised of a bedroom, a bathroom and a kitchen. The entry begins with an open plan where public amenities, such as the kitchen resides. Travelling around the open floor plan, walls defined barriers and living space units. The floating pods are mis-aligned to allow sunlight to penetrate through the home.
perspective

view of entrance and garden space

view of the bedroom and its balcony
A reflective garden sits below an opening in the roof which allows rain water and natural ventilation to filter into the interior.
#2: Beachside House

The beachside house sits three feet off the ground to allow the house to ventilate from below. Columns driven into the concrete basin stabilizes the plinth. Similar to the valley home, this house rises from public facilities to private ones which are visible from room to room. This case study resides on a larger site consisting of eight structural columns and double the amount of pod space: Two bedrooms, two bathrooms, and a kitchen. The alcove rises eight feet which allows for parking below.
Case Study

perspective

view of living room

view of entrance into kitchen
Case Study

The bedroom balcony door can only open when the wall pushes a safety latch on the topside of the balcony rail which allows the door to slide open.

The bathroom shares a wet wall where knobs to the shower and sink basin are located on either side.
Conclusion
Conclusion

Valley house = different wall apertures depends on location of sun

entrance to the bamboo framed home
Conclusion

This thesis is the outcome of my desire to understand the principles of creating an ecological building with bamboo. The premise was that ecological living is viable with the use of a building code and can introduce a new paradigm of constructing housing structures. While much of my invention is to conceptualize a set of parts that are used necessarily for bamboo to thrive, there is also room for cultural influences. That can change the format of the interior and the look of the building. Given the time frame to work on this thesis, I was unable to answer some critical questions which will need additional research. There are four main issues I would like to conclude with and they are: ecological patterns of living, structural properties, precedents on kit of parts, and furthering the design.

The establishment of apartments complexes fit into the idea of ecological living better than a single family home. By developing apartments, fewer bamboo poles would be used and communal space could be created. The open bamboo columns, with independent vertical bearing walls, and a trussed roof, all contribute to design flexibility. More importantly, all apartments will need to embrace the ground plane when being built. No more than two to three stories should be built because of the flammable nature of bamboo and emergency egress within the building.

Additionally, I would like to further my understanding of the structural properties of bamboo, perhaps working with the material at scale to provide myself with the skills needed to obtain a working knowledge. This could answer some of the hindrances in my design. The development of working joint structures that test well under load will benefit my design scheme. This is also the case for the wall unit. Like students at Rhode Island School of Design, examining and testing the physical material in creating a skin structure would allow for new ways to use the material for the wall and pod material. This exploration may improve joinery structures to the transparent or translucent wall.
Conclusion

Beach side house = pods sitting on thickened diagrid wall structure which weaves through out the house

entrance to the bamboo framed home
I would also like see if precedents on “kits of parts” had been invented for bamboo architecture. A variety of joinery explorations from other materials has become my primary inspiration and hopefully by looking into works by architects and engineers that were successful in bringing a product into the mass market. Lastly, I would like to do further research in collecting forestry data for the contemporary U.S. market to see if bamboo is capable of competing in the market. Also, is there a local product in Hawaii currently used in housing that is a good match for bamboo housing? Further expansion on the design would need material research.

Speculations on bamboo’s incorporation into the U.S. market and practices is difficult. The construction currently depends on the expertise of specialized builders that are familiar with building codes and techniques when constructing. Looking at the historical pasts of countries and their implementation of how bamboo has been used, these come to mind: Costa Rica built low-cost housing structures with small diameter bamboo lathed with cement. Asian countries have developed a very intricate pin systems and lashing systems using locally grown fibers. Today there are more than 800,000 people living in bamboo structures in Guayaquil, Ecuador, alone. In Australia, research had begun on interplanting between trees.

Companies around the world has emerged to further the use of bamboo world wide. Taiheyo, a cement company in Japan, has developed a system to strengthen cement by mixing bamboo fibers into the material. Elephant, located in Germany, is a leading exporter of bamboo composite material.
Endnotes
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22. ipgri.cgiar.org/publications
23. network-earth.org/natural-building/bamboo
24. forest-trends.org
26. tifac.org.in/do/amc/case/laminates
Appendix
80 of 91 Bamboo Nursery Locations in the US

Alabama, Dora - www.jmbamboo.com
Alabama, Oakman - www.lewisbamboo.com
Alabama, Oakman - Wolf Creek Bamboo nderoche
Alabama, Springville, Al - www.thebamboogardens.com
Alabama - Steve Ray's Bamboo Gardens
Arizona, Fayetteville - www.attra.ncat.org/attra-pub
California, Vista - www.bambooheadquarters.com
Southern California - www.endangeredspecies.com
California, Sebastopol - www.bamboosourcery.com
California - A Bamboo Shoot Nursery
California - Bamboo Accents
California - www.bamboogiant.com
California - www.bambooheadquarters.com
California - BambooBridge/Bamboo-Depot
California - www.botanicalpartners.com
California - Endangered Species
California - Plants 4 U
California - San Marcos Growers
Florida - www.bamboo4u.com
Florida - www.beautifulbamboo.com
Florida, Columbia – Boone's Farm
Georgia - Big Bamboo Company
Hawaii - www.hawaiibamboosociety.org
Hawaii, Puna - www.awish.net/NorthAmerica
Hawaii, Kawaihae - www.bam boonursery.com
Hawaii, Kawaihae - www.kamuela.com
Louisiana - Louisiana Nursery
Maryland - David C. Andrews
Massachusetts - www.bamboos.com
Massachusetts - www.bamboselect.us
Massachusetts - www.newengbamboo.com
Massachusetts - Tripple Brook Farm
Massachusetts, Plymouth - www.bamboselect.us
Massachusetts, Westford – Burt Associates Bamboo
Mississippi - www.bambooplantation.com
New Mexico - Stone Forest
New York, Cambridge - www.americanbamboo.org
North Carolina - Carol Stangler Bamboo Art
North Carolina - Gardens of the Blue Ridge
Ohio - www.burtonsbamboogarden.com
Oregon, Amity – Broadmead Nursery
Oregon, Ashland – www.tropical-treehouse.com
Oregon, Corvquelle – RKR Bamboo Plantation
Oregon, Corvallis – Nature’s Giants
Oregon, Corvallis – www.teleport.com/~dbrooks/bamboo
Oregon, Eugene – www.artisticgardener.net
Oregon, Florence – Bay Bamboo
Oregon, Gold Beach - www.bamboodirect.com
Oregon, Medford – www.bambooparc.com
Oregon, North Plains – www.bamboogarden.com
Oregon, Portland – www.bamboocraftsman.com
Oregon, Philomath – Evergreen Acres
Oregon, Rouge River – Aficana International
Oregon, Tillamook – www.bambooguy.com
Oregon, Williams – www.forestfarm.com
Pennsylvania - Upper Bank Nurseries
Tennessee, Summertown – Earth Advocates Research Farm
Texas - bambootexas.com
Texas, Houston – Nueces River Groves
Virginia, Crewe – MidAtlantic Bamboo
Washington, Anacortes – www.booshootgardens.com
Washington, Blaine – www.tombsbamboo.com
Washington, Duvall – www.boxhillfarm.com
Washington, Monroe – Anderson’s Bambooland
Washington, Redmond – www.bamboogardenswa.com
Washington, Onalaska – www.landru.myhome.net/burnfridge
Washington, Seattle – Clinton Inc. Bamboo Growers
Washington, Seattle – www.dogscotter.com
Washington, Seattle - www.bamboobuilders.com
Washington, Seattle - www.bamboogardener.com
Washington, Seattle - www.bamboohardwoods.com
Washington, Seattle - Bamboo Guru
Washington, Seattle – Beauty and the Bamboo
Washington, Seattle – Bob Boatsman
Washington, Snohomish - www.jademountainbamboo.com
www.rainyside.com
www.nid.edu
World Bamboo Organization
United States Architects

Cassandra Adams, Architecture professor at UC Berkeley - specializes in construction methods and materials (focus on environmental issues)

Chris Stapleton, US – working with Karl Bareis on the origin of US bamboo

Daphne Lewis, Seattle – detailed species selection for growers in the US Pacific Northwest

Darrel DeBoer, California – resource efficient building components and straw bale projects

Doug La Barre, California - has a manufacturing facility for creating nontoxic adhesives laminated Guadua lumber

Floyd Alonzo McClure, Ohio - went to China (for 24 years) as professor of economic botany at Lingnan University in Canton in 1919. Returning to US and consulted for the US Dept of Agriculture

Jeffree Trudeau and David Sands of Bamboo Technologies, Kawai, Hawaii – UBC standard for bamboo


Kent Fleming, University of Hawaii College of Tropical Agriculture and Human Resources - developed a methodology for calculating the financial and economic cost and return associated with bamboo production

Leimana Pelton, Hawaii - testing different species to establish building codes for Hawaii bamboo construction

Michael McDonough, New York - synthesizing traditional and modern design with new materials & sustainability

Stephen Glasssman – artist of free form structural bamboo site works

Tang Y. Yang – student, Architecture Department at the University of Utah - general information; part of “Toolkit for Sustainable Development”

Timothy Ivory, Michigan – theatre designer and working on temporary and transitional structures
International Architects

Antoon Versteegde, England – Land artist with construction principals
Arata Isozaki, Japan
BAMBUCO, Australia – aerial construction performances by artists with interest in lightweight structures
Bobby Manoso, Philippines
Buckminster Fuller – creator of the Temerity mast, Geodesic dome, and octet truss
Carlos Vergara, Cali, South America - created a multi-column system, used bolts through concrete to create joints
Emeline Navera and Gerald Nelson
Frei Otto, Germany – Tensile architecture with organic free form structures that respond to complex planning
Gernot Minke, Germany - developed a catenaries arch using laminated strips of bamboo
Hiroshi Teshigahara, Japan – Landscape artist that creates outdoor rooms
Kengo Kuma, Japan
Jorge Arcila, Marizales - created a “stacked houses” and is currently writing a history of bamboo in America
Marcelo Villegas, South America - a 60’ tower made of a pole structure linked together with a bamboo roof frame
Renzo Piano, Italy – combines light metal elements (tubes/slabs) with bamboo
Rocco Yim, Hong Kong – means for his static structure and temporary stages or Chinese festivals
Shigeru Ban, Japan - paper tube structures (PTS), creates load-bearing columns, bent trusses
Shoei Yoh, Japan – bamboo as main static structure designing a geodetic cupola and a grating shell construction
Simon Velez, Colombian - use multi-Culm beams, created a bolt and concrete joint for ~ 7 meters cantilever
International Specialists

Jules Janssen, Netherlands – researching and testing the mechanical characteristics of bamboo
Oscar Hidalgo, Colombian - deform bamboo with predetermined wood arc creating strong pre-stressed arches;
developed a system of reinforcing concrete, with Guadua splits woven into cables.
Wolfgang Ebents, Germany – Europe’s largest bamboo grower, 1000 things made with Bamboo
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www.bamboovillagehawaii.org
www.bambooweb.inf
www.bambutece.org/html
www.bamboohardwoods.com/eng
www.basicallybamboo.com
www.bwk.tue.nl/bko/research/Bamboo (Dr. Jules Janssen)
www.city-data.com/city/Makakilo-City-Hawaii.html
www.deccanherald.com
www.desertdomes.com/bamboo (how to make a geodesic dome by Buckminster Fuller)
www.ecotimber.com/flooring
www.iucn.org
www.inbar.int
www.issei.or.jp/Bamboo_Museum
www.mhhe.com/biosci/pae/botany/botany_map/articles/article_38.html
www.michaelmcdonough.com/Bamboo/bamboo.htm (RISD professor)
www.muad.com
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Wayne Winterrowd, Bamboos at the Limit. from Horticulture magazine
Boards

12" x 60" vertical boards
"A meal should have meat and a house should have bamboo. Without meat we become thin, without bamboo we lose serenity and culture itself." Pou Sou-Long, Chinese Poet