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Use of Bamboo in American Architecture and Structural Design

Bamboo is one of the most commonly used building materials ever. Vinay Jain proposes in his construction-based article that it is the structure for over one billion houses and is integrated into many other structures including bridges, scaffolding, and furniture (Jain). According to A.D. Dalbiso and D.A. Nuramo, it's also one of the earliest used building materials ever, found in buildings in China and Africa up to four thousand years ago (Dalbiso, Nuramo). Abundant and easy to grow around the world, this everyday form of architecture would seem to be one of the most common in America, but it isn't. A review by Ermias Amede detailing well-developed bamboo building codes and standards that are prevalent in China, Colombia, Ecuador, India and Peru also concludes there is only one code in America that pertains to building with bamboo: established in 2013 describing a general approach to using lumber composites (Amede, et al.). While it seems reasonable to assume Americans would use such readily available and tried and true building material, the barriers to bamboo use in architecture and structural design are a lot more nuanced, including issues from social stigmas to lack of research in the aspect of engineering. However, all these challenges are worth overcoming to integrate bamboo into a lot more architecture and construction, because of bamboo's ingenious natural structural and aesthetic aspects, incredible sustainability, and low cost.

Structural integrity is the primary benefit to using bamboo as a building material, since it has several advantages over steel or other types of timber. First, in an experiment conducted by

Hongyun Qiu and peers, bamboo's tensile strength (650 MPa) is higher than steel and double that of the average type of wood (Hongyun Qiu, et al.). In his Ted Talk, David Trujillo presents the nodes on the bamboo rods as the main structural element that prevents buckling under pressure (Trujillo). Second, bamboo is a great material to use specifically in disaster/earthquake prone areas (Amede, et al.). Zujian Huang and Yimin Sun compared bamboo to timber and found that since bamboo expresses better hygrothermal (displacement of high heat and moisture) performance than timber, it is much better at resisting fire (Huang, Yimin Sun). Evangelia Frangedaki claims "bamboo is built to withstand wind load," making it a useful material near earthquake fault lines (Frangedaki, et al.). Its high flexibility comes from fibers around the edge that are three times more concentrated than steel (Trujillo). Finally, bamboo exemplifies a balance between low weight and high strength. It is one of the most lightweight building materials because its hollow shape makes it four times more efficient than a solid cylinder (Trujillo). Meanwhile, bamboo retains a compressive strength comparable to steel and two-four times stronger than the average type of wood (Hongyun Qiu, et al.). Overall, these factors contribute to an extremely strong and sturdy material.

On the other hand, building with bamboo has some drawbacks which have disabled the development of building codes in America. Damage from weather, insects, and mold can degrade buildings over time. While this problem could arise with timber as well, the starch within bamboo attracts insects and bacterial growth, while the porous structure allows water to soak in (Jain). While heat treatment solves the problem of mold, Zichou Lou and colleagues prove that it sacrifices bamboo's characteristic structural integrity (Lou, et al.). Therefore, recombinant bamboo (also known as heavy bamboo) is a better alternative, and combining recombinant bamboo with a Fe_3O_4 and rosin coating keeps bamboo hydrophobic and bacterial-resistant while still optimizing structural performance (Lou, et al.). Bamboo can have additional structural weaknesses, and its jointing and foundation performance is lower than other types of timber and especially lower than commercially produced building materials like steel and concrete (Jain). However, developing specific building codes and standards can help clarify the most effective construction methods and rules. As quoted in a journal article reviewing bamboo structural design, “A code tells you what you need to do, and a standard tells you how to do it,” (qtd in Amede, et al.). Some important ideas to consider for these codes can be learned from previous codes in other countries or made specifically for bamboo based on codes for other types of timber, and could include calculations for maximum weight loads, which species of bamboo to use, and how to reinforce bamboo. Bamboo reinforcement, like timber reinforcement, is a long-used technique, and even traditional bamboo houses were woven around thicker juniper poles (Dalbiso, Nuramo). As stated by A.D. Dalbiso and D.A. Nuramo, “Valuable lessons from vernacular [architecture] can be integrated with the modern to produce sustainable designs,” (Dalbiso, Nuramo). While bamboo comes with specific durability disadvantages, chemical treatment and structural reinforcement can make it a viable option for commercial building use.

Once building codes are well developed and the engineering aspect of building with bamboo is further researched, architecture and design can come into play. Bamboo’s look can be altered in both the growth and processing stages, using techniques such as growing in a box to produce square rods or bending bamboo with heat and pressure (Jain). There are many different bamboo building materials that can add variety to bamboo architecture, including particleboard, mat board, bamboo MDF, bamboo OSB, corrugated roofing sheets, beams, flooring, glulam (laminated bamboo), and strand woven bamboo (Hongyun Qiu, et al.).

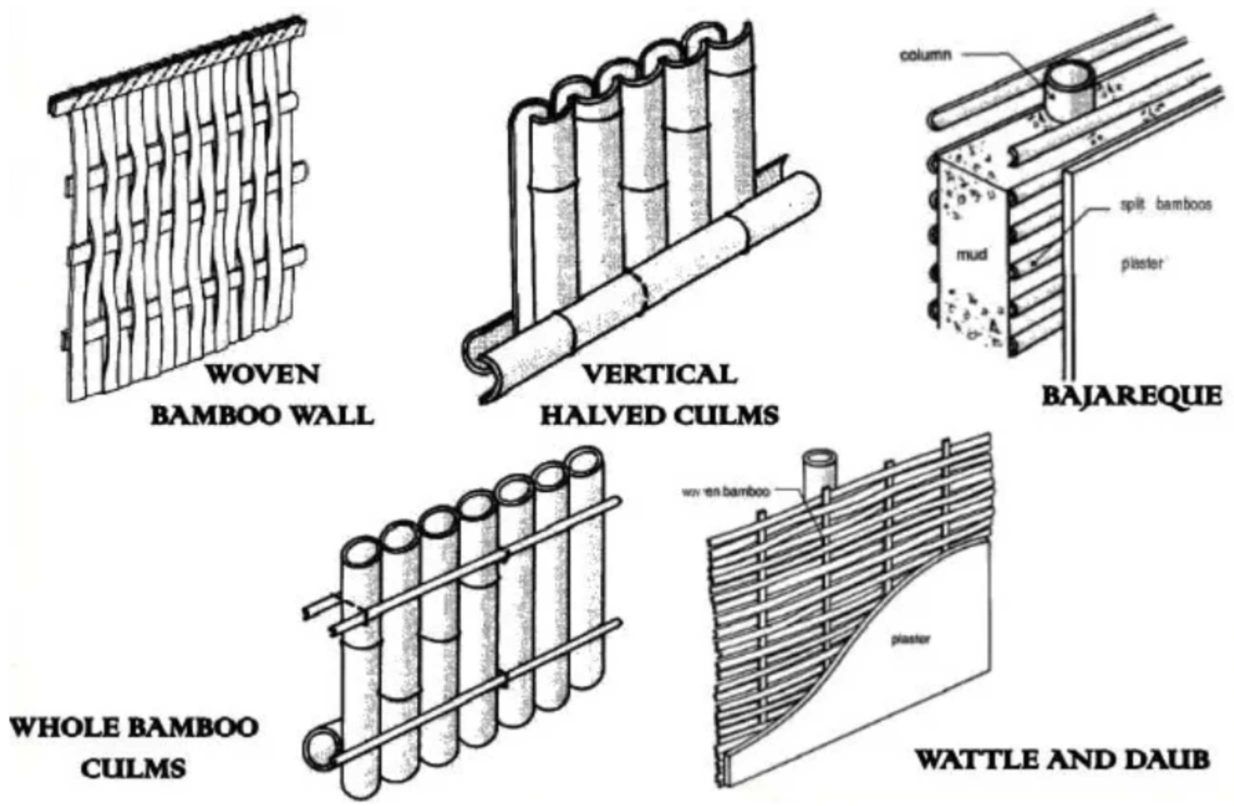

Figure 1. Types of Bamboo Walls (Jain, Vinay).

Besides using different species and colors of bamboo, these can be constructed in different ways to add decorative aspects to each structure, such as weaving strips, wattle and daub, bajareque, and overlapping bamboo culms (see Figure 1). One popular application of bamboo in architecture is biomimicry, or borrowing design aspects from trees (Frangedaki, et al.). This doesn't imply a treehouse, but could mean using the canopy shape of treetops for a roof, or the integration of rounded/angular walls. Whatever design an architect is going for, bamboo is a very versatile option.

Although designing with bamboo might be interesting and artistic for architects, lack of publicity and social stigmas surrounding bamboo leads to a huge lack of demand in America, meaning bamboo houses are not designed. Nicknamed "poor man's timber," Kyle Schumman claims that media depictions and primitive representations of bamboo housing in American art are the biggest contributors to the stigma that bamboo is a sign of poverty (Schumann, et al.). For example, many TV shows/movies portray building with bamboo out of necessity after being stranded on an island, and representations of bamboo buildings in America are poorly made and primitive. Unfortunately, this stigma does stem from some truth, and many living in developing countries have bamboo houses that they would prefer to upgrade to some type of concrete masonry (Trujillo). In order to alleviate the negativity of this stigma, integration of nice-looking bamboo housing in developed countries such as America could help present a positive example for all countries (Schumann, et al.). This could mean concealment or combination of bamboo with other building materials, or finding new decorative geometric designs and patterns to build with using bamboo. Lastly, commercializing bamboo will help promote bamboo building products that perform as well as (if not better than) their timber equivalents (Huang, Yimin Sun). More research and publicity will help with all of these issues and boost demand for bamboo housing.

Perhaps the biggest and most specific benefit to building with bamboo is its incredible sustainability. According to an academic article by Hongyun Qiu, “bamboo is a renewable biomass material that has a high annual output of biomass per area of land.” Not only is bamboo abundant around the world, but its use also releases fewer CO2 emissions than any other building material (Frangedaki, et al.). This is because bamboo stores ten kilograms of carbon for every one kilogram needed to process it (Trujillo). Lowering carbon footprint is especially crucial in the architecture, engineering, and construction (AEC) industry, since it is responsible for 39% of greenhouse gas emissions (Frangedaki, et al.). One valid counterargument is that timber reduces roughly the same amount of carbon dioxide as bamboo. What sets bamboo apart from timber in carbon sinking is that it grows quickly, requiring only 6 months to reach harvesting size; “it’s a more accessible weapon in the fight against carbon" (Trujillo). When considering overall dollar cost and CO2 emission cost, bamboo is the more sustainable option.

There are several ways to reduce carbon footprint even more by altering processing methods for bamboo. A study by Xiaoxiao Xu shows that "using natural gas in carbonisation and drying processes of bamboo production would reduce CO2 emissions by almost half," (Xu, et al.). Additionally, transportation is the highest carbon cost in the processing of bamboo, and combining frontend and backend factories would nearly eliminate it. Finally, skilled workers and higher-quality machines could reduce excess adhesive use in the gluing process of transforming bamboo into building sheets. All of these solutions are relatively easy fixes, but not necessarily important in the public eye. If sustainability is compared, bamboo fully wins over steel, concrete, and even other types of timber. Bamboo also costs less than these other commonly used building materials, which is generally uncommon for sustainable products. It just depends on whether sustainability is a value building companies and the AEC industry are willing to consider.

There are already many solutions in place for the integration of bamboo into American architecture, but more research and publicity of research is required to popularize its use. First, different ways of combining/reinforcing bamboo with steel or concrete should be tested and optimized to get the benefits of both, and an economical, working treatment to prevent weather damage needs to be standardized. Further research in these areas will lead to the promotion of developing attractive designs with bamboo to defeat stigmas, and more detailed building codes/standards. This will ultimately result in a higher demand from both building companies and the public because of its high sustainability value, and an increase in bamboo use in American architecture and structural design.

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