LOCALLY PRODUCED LAMINATED BAMBOO LUMBER: A POTENTIAL SUBSTITUTE FOR TRADITIONAL WOOD CARVING IN GHANA

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ABSTRACT

This study examines the prospective of laminated bamboo lumber as a complementary substitute for traditional wood carving in Ghana. Technically, the production of laminated bamboo lumber requires heavy duty fabricated equipment and rigorous pressing processes normally found in commercial fabrication houses. This paper, however, concentrates on fabricating locally sustainable laminated bamboo lumber using simple but pragmatic, appropriate technology that can be managed by the local carvers. The characteristic attributes of the resultant laminated bamboo lumber verified through the experiments conducted indicated that the end product is robustly suitable for carving Akuaba doll, mask, Oware, wooden comb and the traditional Akan stool. The conclusion was that a suitable simple methodological approach has been achieved using locally available materials and inexpensive tools to produce the substitute lumber for carving. In view of the outcome of the experiments, it is encouraged that the traditional carving industry utilize the laminated bamboo lumber as a complementary resource material for carving. It is therefore recommended that further research be made on its use as a carving material for contemporary craft products to curtail the over dependency of conventional wood species in the country.

Keywords: Laminated Bamboo, traditional carving, wood substitute, appropriate technology.

INTRODUCTION

The depletion of wood material resources in Ghana makes it imperative to exploit other material resources like bamboo as a complementary resource material for wood due to its great developmental potentials. Wood, as a natural resource for traditional carving in Ghana has become a major concern in the wood carving industry and the sustainability of this industry is in doubt. Bamboo culture has a long history in Ghana as a natural renewable material, though not developed, has wood characteristic and potentials capable of alleviating the problem of wood depletion. A sustainable natural available material, appropriate for the development and use by the traditional carver, the researchers advocate, is the laminated bamboo lumber. But the production of laminated bamboo lumber imported or made in the country requires heavy sophisticated fabrication equipment, methods, in addition to labour cost and other financial constraints, makes it a disincentive to manufacture locally.

In most regions of the world, laminated bamboo lumber is utilized to create furniture, floor tiles, balustrades, and decorative crafts. Bamboo in Ghana like many other African countries, are used as basic constructional materials, traditionally used for silos, houses, farm boundaries and fish traps. This multi-purpose giant grass, possesses mechanical properties similar to wood. Recently bamboo has received a level of considerable interest as a sustainable material in the furniture industry, due to its fast growth rate (Lee et al, 1994: Rittironk et al, 2008, & van der et al, 2006) and its ability to develop in various soils. It matures faster than most forest species and attains a full height within 2– 4 months and a maturity period of 3–8 years (Lee et al, 1994, & Liese, 1987).

The differences between bamboo and wood are several. The rays or knots, nature of bamboo, gives it a far more evenly stress distribution throughout its length. According to van der Lugt et al, (2006) the structural function of bamboo is eco-friendly, capable of repossessing large amounts of land carbon storage of 61.05 tons per hectare in bamboo villages. The diameter, thickness of bamboo, the inter-nodal length, the distribution of macroscopically graded structure and the fibre microscopic graded structural design, lead to favourable properties of bamboo (Amada et al, 1997). Bamboo can be glued very well since it does not contain the same chemical extracts as wood (Jassen, 1995). Laminated Bamboo Lumber is usually produced as a rectangular cross-section board fabricated by flattening bamboo culms and gluing them in masses to form a bonded composite (Nugroho et al, 2001 & Sulastiningsih et al, 2009).

Developing the art of laminated bamboo lumber fabrication locally would help traditional wood carvers to minimize waste, cost and customize production to suit their intend purposes and promote tree conservation and growth. Baah, (2001), suggest that there are seven known species in Ghana. These are bambusa arundinacea, bambusa bambos, bambusa multiplex, bambusa pervariabilis, bambusa vulgaris, and bambusa var. vitata and dendrocalamus strictus. Among these, Bambusa vulgaris is indigenous to Ghana.

Conventional Uses of Bamboo in Ghana

Untreated bamboo comparatively has a short life span, and customarily used for purposes that do not necessitate much permanence. The culms, are split for fencing, for courtyards, outdoor kitchens and bathrooms in rural homes and low-income areas in the metropolises (Rudolf et al, 2013). Culms, split into two halves are used to provide temporary roofing that last two or three years. Split or whole culms are used to make seating benches that are fixed to the ground, often under shady trees to provide relaxation. Spoons, spatulas and sharp spikes are made from the split culms for various purposes, such as roasting sticks, for kebab and spikes for removing snails out of their shells.

Unconventional Uses of Bamboo

In the building and construction industry, Rudolf et al, (2006) alleged that the scarcity and expensiveness of Wawa poles, once used as props for scaffolding and for casting concrete flooring, have been replaced with bamboo culms. In the furniture industry, rounded woods are introduced into the hollow part of the bamboo culms for the fabrication of furniture. Boateng et al (2013) opined in more recent years the technique of splitting the culms of Bambusa vulgaris into slivers for various purposes is becoming a novel practice. Bamboo slivers are being used to weave baskets and basketry-related products. Most of today's bamboo wooden floor board of this kind originates from China and other parts of Asia. Moso bamboo is the species most commonly used for boards.

Relative advantage of bamboo to wood lumber

Bamboo is an attractive alternate material to hardwoods because of its physical similarities. Its strength and durability as well as its resistance to insects and moisture, and Eco friendliness makes it an ideal substitute for wood. The stiffness of traditional bamboo boards ranges from 1180 (carbonized horizontal) to roughly 1380 (natural), while newer manufacturing techniques including strand woven bamboo range from 3000 to over 5000 using the Janka hardness test

(Chung et al, 2002). Comparatively Janka hardness of bamboo (6,270 N to 7,170 N) is much higher than that of Mahogany (4,760 N) (Table 1).

Bamboo panels are prepared from mature bamboo culms and these culms are crosscut to length and then slit into strips depending on the width desired. The natural bamboo colour is similar to beech wood. If a darker colour similar to oak is desired, the bamboo goes through a carbonizing process of steaming under controlled pressure and heat or dyeing. Invariable the carbonizing process, reduce the hardness of the bamboo board significantly, compared to non-carbonized bamboo and this renders it softer than some common red oak. Compared to other materials, such as particle boards in the lamination process, most bamboo boards uses a relatively small amount of urea-formaldehyde adhesive though harmful volatile to indoor air quality. The panels are then heat pressed to cure the adhesive which is later planed, sanded, milled and finalized with an ultraviolet curing lacquer.

Bamboo has strong mechanics and good adaptability, it is easily processed and has a wide range of usage in construction and engineering. The tensile strengths of bamboo are about that of wood and the compression strength is approximately 10% higher than that of wood (Mathew et al, 2002). Different from trees, bamboo grows initially at full width, with no tapering or horizontal growth. Bamboo grows up to three feet a day. And in one year, reaches its full height, as the stem continues to harden. The strength of the bamboo continues to increase for the next two to four years; most bamboo species are considered fully mature in two to three years with tree size ranging from 15-30m tall (Table 1). Below is the comparative strength between bamboo and wood.

Table I: Comparison between strength of bamboo and wood

Items	Bamboo (Phyllostachys and Bambusa genera)	African Mahogany (Khaya. Ivorensis)
Tree Size	50-100 ft. (15-30 m) tall, with a 3-6 in (10-20 cm) diameter	100-130 ft (30-40 m) tall, 3-5 ft (1-1.5 m) trunk diameter
Average Dried Weight	31 lbs. /ft3 (500 kg/m3) to 53 lbs. /ft3 (850 kg/m3)	40 lbs/ft3 (640 kg/m3)
Specific Gravity (Basic, 12% MC)	38 to .64, .50 to .85	52, .64
Janka Hardness	1,410 lb.f (6,270 N) to 1,610 lb.f (7,170 N)	1,070 lbf (4,760 N)
Modulus of Rupture	11,020 lb.f/in2 (76.0 MPa) to 24,450 lb.f/in2 (168.6 MPa)	13,190 lbf/in2 (91.0 MPa)
Elastic Modulus	2,610,000 lb.f/in2 (18.00 GPa) to 2,900,000 lb.f/in2 (20.00 GPa)	1,537,000 lbf/in2 (10.60 GPa)
Crushing Strength	8,990 lb.f/in2 (62.0 MPa) to 13,490 lb.f/in2 (93.0 MPa)	7,100 lbf/in2 (49.0 MPa)
Shrinkage:	Diameter: 10-16%, Wall Thickness: 15-17%	Radial: 4.2%, Tangential: 5.7%, Volumetric: 10.0%, T/R Ratio: 1.4

Source: http://www.wood-database.com/

Environmentally it takes approximately 3–5 years for bamboo to reach full maturity, but traditional hard woods can take 20–120 years to mature. For example, Moso bamboo, a primary species used for laminating, grow up to 47 inches in 24 hours and 78½ feet high in 40 to 50 days. Harvested Bamboo needs no replanting, because the root system in the soil is left intact after harvesting. Apart from the rhizome root structure, having the ability to hold the soil in place to prevent erosion, (Liese et al, 1987) its horizontal stems that grow below the soil surface reproduce itself to colonize an entire area. Conversely seedlings of wood plants need to be planted each time a tree is cut down.

Mahogany, chosen comparatively with bamboo is considered one of the most important timber, emerging as one of the fast growing (rotation 35 years) good timber quality species for local wood carving (Opuni-Frimpong, 2006). Relatively, the specific density of Mahogany at 12% of moisture content is fairly at par with that of bamboo though the later seems to be a little higher in some cases than that of Mahogany (Table 1). However, Anonymous, (1994) reports that Mahogany has an average density of 0.55g/cm3 at 12% moisture content, which makes it a suitable species for joinery, doors and window frames, boat constructions, as well as veneer and plywood production.

Traditional trees in Ghana

The land area of Ghana is about 230,020km2 with the savannah occupying 65.5%, of the land area to the north (almost covering 15.6 million ha) with the moist forest taking up the remaining 34.5% (8.2 million ha). Timber logging and harvesting is mainly concentrated in the moist forest region of Ghana (Hawthorne et al, 1993).

The timber species dominating the timber trade in Ghana, among many developing species are the Entandrophragma cylindricum Sprague (Sapele), Khaya ivorensis (A. Chev), (Mahogany), Terminalia ivorensis A. Chev. (Emeri), Terminalia superba Engl. & Diel., (Ofram) and Aningeria robusta (A. Chev.) Aubrev. & Pelleger, (Asanfena). Others include *Afromosia, Kokrodua, Kyenkyen, Odum, Dwuma, Sese, Twenebua, Wawa, Onyina* and *funtum*. The timber may be found in solitary or multiple groups and also differ in size among and within species. (Hoadley, 2000). These hardwood species, i.e. *Asanfena, Emeri,* Mahogany, *Ofram* and *Sapele* are commonly found in the export market and these are utilized for several applications, such as quality furniture and joinery, doors, frames, boat building, veneer, plywood, turnery and carvings (Anonymous, 1994).

Traditional carving in Ghana

Agreeing to the Boateng, (2011) a research fellow of the Ghana National commission on culture for UNESCO, carving in Ghana begun as a communal sort of construction based on the thoughts and ideals of the entire residential area or cultural group. Deviation from community or acceptable standards of expression into other aesthetic expression using wood or other media was tabooed by the community. He further reiterated that carving was done expressively under the strict dictates of clan leaders, religious leaders, chiefs and other opinion leaders. This allowed very little room for individual expression and creativity. Nevertheless, carving still sustained communal and social life in many ways carving produced a multiplicity of drums for traditional orchestra cohesion and entertainment.

Carving according to Boateng, (2011), provided for a wide range of household equipment. Examples of these are mortar, pestle, wooden bowls, ladles, combs, stools, chairs, walking

sticks, linguist staves and countless arrays of traditional games. The rest included canoes, hoe handles, boxes, beds, cupboards, swords and many more. Carving is the analytic study of the medium using the requisite tools to remove the unwanted parts to arrive at final product which has been previously conceived in the mind of the carver. It requires the use of a particular set of carving tools in order to facilitate easy carving process and the realization of the ultimate goal.

The trees for carving were not felled off hand without passing through certain ritual purification methods. The trees for carving were considered during those days as abodes, dwelling places or receptacles for certain unseen spiritual forces or supernatural spirit and powers. Some of these supernatural spirits, according to Akan mythology were at certain times very violent and malevolent. Others were considered to be friendly and benevolent. Then in order not to get the ire of any malevolent spirit inhabiting in any of these wooden species for carving, it was proper to proceed through certain ritual purification practice to dislodge these supernatural spirits to make it accessible to the sculptor. At certain times, rams, fowls and a bottle of schnapps or other alcoholic beverages were used in these rituals to dislodge completely a strong spirit. The sacrifices offered varied in their presentation due to the demands of the malevolent spirits.

The extraordinary beginnings of the carving profession embodied the manufacture of carving tools. Carver's manufacture their own set of tools from iron and pacified the tools before using them. Special libation prayers were offered to the ancestors and the gods to protect the carver from injuries during the use of the carving tools. During the purification rituals, strong alcoholic drink and fowls were slaughtered on the tools as special libation prayers were offered. These restrictions restrained many carvers from felling trees indiscriminately, but the lift of these practices gave in to wanton depletion of the forest to the detriment of the ecological balance of the entire community. Using laminated bamboo lumber for carving will ultimately go a long way to preserve the forest and minimize these ritual traditions if it still lingers on, since such believe does not extend to bamboo harvesting. The high demand for wood consumption makes it imperative and urgent to find a substitute.

For effective use of this environmentally friendly lumber material, various experiments were done to ascertain the appropriate fabrication techniques, to attain the right mechanical properties for its use as a viable carving material (Lee et al, 1998: Nugroho et al, 2001).

Mechanical Features of Bamboo

Bamboo after fabrication, processing, has strong compressive and tensile strength, strong rift grain, compressive strength, and high ratio of mild, lightweight and strong anti-pressure performance, excellent elasticity and toughness, which is hard to shrinkage and deform. Due to resisting reinforcing effect, bamboo stress evenly with a secure physical and mechanical performance similar to steel (Chung et al, 2002). No wonder it is referred to as plant steel due to its strength compared to other building material next to steel. The effectiveness of tension and the intensity level of pressure of bamboo is about three times and about two times that of wood respectively. It has thick skin, with a hollow in the inside, which account for its strong bending firmness (Sharma et al, 2015).

The visible characteristic of bamboo is the growth joint that happens in every section, and the cross section of its firm surface. The experimental results conducted by Peng et al, (2015) validate joint bamboo section as a stronger pliable inflexibility more than other similar wood

joint section. The results of the study conducted by Sharma et al, (2015) also indicate that laminated bamboo lumber products have properties that compare with or surpass that of timber.

Mechanical and Physical Properties of Bamboo

One very important requirements upon which a material can be investigated to qualify as a substitute for another, is its mechanical and physical properties. This is to have an appreciable insight into whether bamboo can perform as well as wood. The major characteristics of a bamboo are its high tensile strength, good weight to strength ratio, able to withstand up to 3656 Kg/cm2 of pressure. Its strength-weight ratio, supports its use as a highly resilient material against the exertion of force (Chung et al, 2002). Bamboo can easily be worked on using simple tools and machines.

This renewable raw material, when properly treated and technically processed, can have an applied life of 30 to 40 years. Bamboo has been established as an environment-friendly, engineering, energy efficient and cost-effective production material with varied options. The application of heat and pressure used to curve or flatten the cut stalks is a well-known traditional method, that enables (Calkins, 2008) bamboo to be laminated into sheets and beams. This process involves cutting stalks into thin strips, planning them flat, and boiling and drying the strips; then glued, pressed and finished (Te Roopu Taurima, et al, 2014). Bamboo intended for production is commonly treated with a mixture of borax and boric acid solution as a fire retardant and insecticide to resist insects and rot. The next process is to boil the cut-out bamboo to remove the starches that attract insects.

The quality of a laminated bamboo lumber is dependent on the manufacturer and the maturity of the plant harvested (six years considered the optimum); as the strongest bamboo is claimed to be three times harder than oak hardwood though others may be softer than standard hardwood (Te Roopu Taurima, et al, 2014). Like timber, bamboo is identical and exhibits properties with different values when measured in different directions (anisotropic material). Similar to wood products like cross laminated panels, the approach of producing a rather same material by cutting and reassembling is adapted to bamboo. Cross lamination of layers decreases its anisotropic qualities and makes laminated bamboo exhibits the same behaviour as timber products.

Manufactured bamboo boards are made available in beams with varied grain orientation. With vertical orientation bamboo boards, the component pieces are made to stand vertically on their narrowest edge and then press laminated side to side. This effect reveals a uniform surface outlines, similar to most finished grain woods. On horizontal bamboo board, the slats are arranged in a horizontal direction, on their widest edge, and then joined side by side with adjacent pieces using a high-pressure laminate system. Though the characteristic nodes of the bamboo are visible on the finished horizontal surface, its varied orientation arrangements enhances its strength compared to conventional wood boards.

This study adopted the physical properties of the most commonly used carving wooden material such as mahogany as the benchmark in order to examine the potential of laminated bamboo lumber to substitute structural wood lumber. Comparing the physical properties of bamboo to that of the most commonly carved wood confirmed that all bamboo culms ‘physical strengths are greater than the physical strengths of the mahogany. In short, the physical strengths of the bamboo are superior compared to the physical strengths of mahogany (Table 1) and this affirmed the possibility of using bamboo as an alternative material. However, the

dimensional stability, the shrinkage rate indicates that bamboo seems to be more easily affected by the changes in environmental moisture but equally comparable to mahogany. The productivity of bamboo is also affected by the age structure of the bamboo culms high proportion of old culms tends to diminish since the old culm is relatively low in productivity. Old culm is also weaker compared to young culm, which causes them easily attacked by insects or pests.

MATERIALS AND METHODS

The following materials were used: bamboo, PVA, gloves, brushes, pencil, tape measure, sand paper, sanding sealer, wax, thinner, lacquer, nails, and polyvinyl acetate glue, and pyrinex 48EC, kerosene. Tools and equipment employed in the project included, clamp, splitter, Try square, steel rule, marking gauge, cutting gauge, crosscut saw, rip saw, tenon saw, Jack plane, smoothing plane, spoke shaves, chisels, mallet, gouges, files, screwdrivers, machete, pincers, hammer, G-cramp, sash cramp, bench saw, surface planer, thickness machine, orbital sander, hacksaw blade, and soldering iron.

The Research methods employed the Experimental practice base research that depended on studio activities, Descriptive and Analytical. The research tools employed are interviews, observations and photography. The fabricated work done by the researchers was the laminated bamboo lumber for the various experiments conducted. Firstly bamboo culms were split and constructed into boards and beams, and later carved and constructed into various artefacts. Other images and figures were also carved with gouges, and finally polished with lacquer to enhance their beauty. The descriptive research method was used to describe existing conditions and the experimental research method was used for the designing and carving with laminated bamboos to ascertain its feasibility. This research method was also used to assess the suitability of the requisite tools and materials for the making of both the laminated bamboo lumber and the sample carving products. Critical reflection of the materials, tools, equipment and the technique are always paramount in carving.

Data Collection

The bamboo for the various experiments were collected from the Kwame Nkrumah University of Science and Technology, Kumasi, (KNUST) botanical gardens where the used bamboo grows.

Observation Method

The required data used were collected through observation and interviews. The samples bamboo selected were used for the experiments or tests to ascertain its mechanical capabilities. Observations were made and the results recorded whiles workers at the KNUST botanical gardens were interviewed on the utilization of bamboo.

Harvesting, Preservation and Experimentation

Harvested Bambusa Vulgaris was selected based on the following criteria, knowing; the homogeneity along the trunk, the absence of defects such as parasitic attacks, fungus, rot, hollow size, the quite thicker trunk without distortions, minimal presence of a branch node protrusion, and almost the same length space and height.

The dry bamboo culm were cut into segments 150 cm in length, 5 cm longer than the sample length. The additional length was to allow for losses due to cutting and any modifications. The selected bamboo culm were grouped into two (A, &B) and the A group were stocks completely in water for twenty-one days. This was performed to cut down the carbohydrate content of the bamboo and visually determine the extent of harm that have been caused by weevils and pest if any for subsequent elimination. This was later dried under a shed for a period of three weeks. The B group of bamboo was also dried in the open air for a period of three weeks. Observation proves that the bamboo culm placed in the open air developed cracks along the surfaces due to the fast rate of drying whereas those located under the shed exhibited negligible cracks (Fig., 1a). This observation agrees with Larbi, (2003) that bamboo should be seasoned under a shed on a raised platform twenty five centimetres above the ground in a well-ventilated area. Larbi (2003) reiterate that this method preserves bamboo for at least ten months. After going through the seasoning process it was later observed that the B group bamboo left untreated under the sun was attacked by insect and fungi and within two months everything was destroyed due to its low resistance to biological degrading agents, micro-organism and insects that attack bamboo in any construction application (Fig., 1b). Care must therefore be taken in respect of the durability of bamboo used in the production of artefacts.

Fig., 1a: group B of bamboo culm dried in the open air exhibited cracks within 2 weeks

Fig., 1b: group B of bamboo attacked by insect and fungi after the seasoning process for 2months

Source: from Authors

To improve on the durability of the bamboo, the selected bamboo from the A group were boiled at a constant temperature of about 40^0C for three hours. This was done to kill the micro-organism in the plant and also to neutralize better the sugar content of the bamboo, which forms the principal ingredient for biological degrading agents (Baah, 2001). In this way, the attack on this bamboo by biological degrading agents in future will be practically negligible. The A group went through further chemical treatment to improve the durability of bamboo by employing Pyrinex 48EC, an agro-chemical mixture in the proportion of ¼ (one- quarter) of Pyrinex48EC to 2 (two) gallons of water. The bamboo was immersed in this solution for 3 (three) days, then removed from the solution and dried in a shed. To hasten the preservation process, one (1) gallon of Kerosene was introduced into the mix.

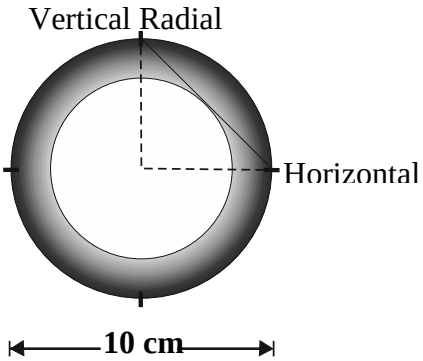

Fig., 2: Strip

The choice of the bamboo used in this study for the construction of the laminated bamboo had an age range of 2-4 years and a diameter of 7-30 cm, defect free, straight and mature. Length and diameter of the culms were 150 cm and 9-10 cm respectively (Fig., 2, 3a & 3b). The items to be carved determines the width, length and height of the laminated bamboo lumber as well as the diameter size of the bamboo culm and the orientation of the strip for the laminating process (Fig., 2 & 3a). Sharp knife was then used to split the bamboo into various sizes ranging from 10 cm thin slivers and above (Fig., 4 &5). The outer and inner layer of slivers, which contain silica, wax and parenchyma, was removed to increase the bond ability of the slivers.

Fig., 3a: Cutting the bamboo length of 150cm

Fig., 3b: Cross cut bamboo ready for splitting

Source: field work

The chemical solution of Pyrinex48EC and Kerosene was also applied to the surfaces of the split cutlass as well as the strips for the laminated board with brush and dried under a shed. The Kerosene diffuses through the pores and the parenchyma cells of the striped bamboo, to preserve it.

Preparation of the laminated bamboo

After the seasoning and the preservation process, the machete and the splitting machine was used to split the culms which were cross cut (Fig., 3a & 4) with a saw to appreciable lengths of approximately 10-14 cm in diameter (Fig., 2).

Fig., 4: Splitting of bamboo

Fig., 5: Split bamboo

Source: *field work*

The research used a chisel to remove the inside nodes in the strips to flatten and give way for easy smoothening (Fig., 6). The strips were smoothened with coarse sandpaper to allow the fibrous material to appear on the front, back and sides of the laminated composite (Lee et al, 1998) (Fig., 7 & 8). An adhesive (polyvinyl acetate glue) proportion of approximately 180 g/m2 was manually applied onto the strips for the lamination process.

Fig., 6: Planning of the bamboo

Fig., 7: Planed bamboo

Source: *from Authors*

The prepared members of the strips were arranged flatwise with each other in a gadget frame to help align the strips orientation firmly during the laminating process (Fig., 9). To avoid potential cut failures in the composite lumber applications, the stacks were arranged so that the inner surfaces of the middle layers formed the centermost lines, and the inner surfaces of the outer layers contacted the outer surfaces of the inner layers (Nugroho et al, 2001) (Fig 9).

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Fig., 8: Drying of preserved bamboo

Fig., 9: Gluing and pressing of bamboo strips.

Source*: field work*

The clamped strips were left in position for about two to three days in order to achieve a firm and compact bond for a proper flattened laminated bamboo. The surfaces and sides of the laminated board were later planed and smoothened (Fig., 10) It is interesting to note that during the flattening process, none of the stacked strips experience any crack or split as a result of the appropriate seasoning, adhesive application and conditions given to the preparation of the bamboo.

Fabrication of laminated bamboo lumber

The methodology chosen for the production of the laminated bamboo lumbers required handy equipment that were available or feasible to acquire in some wood carving centres where bamboo is also usually available. The splitting of the bamboo, the flattening of the culm, the gluing, the pressing and the sanding of the lumber composite were all done with available appropriate handy tools and equipment. Two or more laminas were manually pressed at a time using clamps to exert the required pressure of 0.6 MPa for 4 hours. The orientation of the original strip within the beam, were either edgewise or flatwise. Though the process is labour intensive, it is adaptable to the wood industry.

Fig., 10: Laminated bamboo strips set for planning

Fig., 11: Gluing of opening in the laminated bamboo

Fig., 12: Samples of the laminated bamboo boards

Source: *from field work*

Carving Traditional Ghanaian Artefacts with Laminated Bamboo

Five experimental samples were made with varied laminated bamboo block measurements depending on the product and product size. All samples went through a series of sketches and the desired results, selected out of the lot. Items produced are the Traditional stool (Fig., 13a), Akuaba fertility doll (Fig., 14a), Oware (Fig., 15a), Mask (Fig., 16a) and a Wooden Comb (Fig., 17a).

Experiment I: The Traditional Stool

Traditional stools are normally carved from local timber species ('Sese' and 'Afromasia') used because of their softness and unique characteristics. This project has proven that laminated bamboo made from three year old bamboo can attain almost the same softness properties of 'sese' to produce a traditional stool (Fig., 13c). The laminated bamboo block for this sample measured 60cm x 30cm x 12cm. This was used to produce the seat and the base trimmed with a band saw to give them the needed slight curved surface per the design agreed upon for the traditional stool (13a & 13b). The two middle supports of the stool made from an 8cm square thickness of laminated bamboo, were also cut to design size with a band saw. Additionally the mortise and tenon joints were constructed under the seat and the base of the stool and the middle section fixed in position to support the seat and the base of the stool (Fig., 13c). All parts of the stool were sanded before the assemblage and bonding with bondex glue. A Sandy sealer was then applied on the surface of all the members to seal the pore spaces and allow the coating of the glazed wax to spread evenly on the bamboo surface. This was done to accentuate and enhance the appearance of the traditional bamboo stool (Fig., 13c).

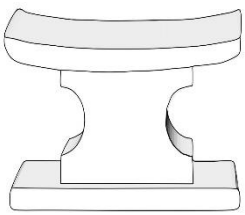

Fig., 13a: Corel draw rendition of Traditional Stool

Fig., 13b: Rhino rendition of Traditional Stool

Fig., 13c: Final work of Traditional Stool

Source: *From Authors*

Though a lot of time, energy and materials were needed for the production of the stool, less carving or chopping of the lumber was required. However, working with laminated bamboo lumber demand the use of well sharpened tools.

Experiment II: The Akuaba doll

Like the traditional stool, Akuaba doll is carved from the Sese and Afromosia woods, but the lamina used was made out of a one year old laminated bamboo. Akuaba doll, referred to as the fertility doll (Fig., 14a) is embedded with mystical beliefs that has the propensity to make a barren woman give birth to a child, when wrapped at the back, a symbol of fertility among most communities in Ghana. It is also used as a decorative piece in the living room or the bedroom. The sketched Akuaba doll (Fig., 14a & 14b) was transferred onto the laminated bamboo block measuring 30cm x 15cm x 10cm. To prevent the doll from split due to pressure exerted by the tools with the mallet, very sharp chisels and gouges were used. The outline of the design were first marked with the v-gouge and the narrow band saw used to cut the image out of the block. The U-gouge was used to block out the design and the Akuaba doll, dressed with various chisel sizes and sharp carving knives. Various grades of sandpapers were then used to smoothen the Akuaba doll starting from grade 60, which is the roughest to 80, 120 and finally grade 160 which is the smoothest. Sanding Sealer was then applied to seal the pore spaces on the surface of the Akuaba doll and then applied with the wax. The result was the laminating Akuaba doll with exciting colour and appearance (Fig., 14c)

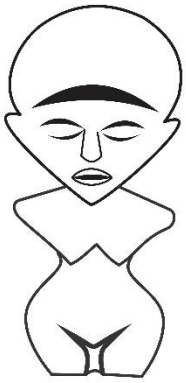

Fig., 14a: Corel draw rendition of Akuaba Doll

Fig., 14b: Rhino rendition of Akuaba Doll

Fig., 14c: Final work of Akuaba Doll

Source: *From Authors*

Experiment III: The Oware game

Oware (Fig., 15a), carved with soft woods like *Sese* and *Afromosia*, is one of the traditional games played among the Akan speaking people of Ghana. History records that the Denkyira king *Ntim Gyakari* was captured and beheaded by the Asante's while playing Oware, with the wife at his residence in the heat of battle. The designed *Oware* game was produced out of two laminated bamboo blocks measuring 44cm × 4cm ×7cm each made from a two year old culm. Six (6) circular depressions which contain the four (4) small marbles were carved with a radius of 5.5cm in each of the laminated bamboo blocks using the C- gouge (Fig., 15a & 15b). Slight dented grooves were provided for the hinges to join the two blocks together as a whole piece. Various grades of sandpaper were used to smoothen the carved surfaces to give the laminated bamboo block a circular curvature. This was followed with the sanding sealer applied to seal the pore spaces on the lumber surface.

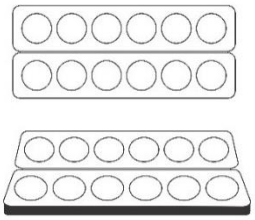

Fig., 15a: Corel draw rendition of *Oware*

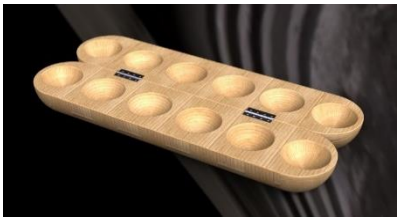

Fig., 15b: Rhino rendition of *Oware*

Fig., 15c: Final carved work of *Oware*

Source: *from Authors*

Two small size hinges with screws were then fixed in the grooves created to join the two blocks together for easy closure (Fig., 15b). The *Oware* game was then coated with wax to give it a neat finished. The advantage of this design form was its ability to be carried along or transported easily from one place to another due to its convenient cute design (Fig., 15c).

Experiment IV: The Mask

Mask (Fig., 16) plays an important role in the Ghanaian traditional set up. Masks are used for decorations, agriculture as well as spiritual purposes. The mask can be hanged in the offices and in the living rooms. The sketched, designed mask (Fig., 16a & 16b) was transferred onto the laminated bamboo block measuring 33cm x 10 cm x 4 cm and its outline drawn with the V-shape gouge. Various U and C shaped gouges and chisels were used to carefully carve the mask per the design. Several grades of sand papers were used to smoothen the mask, starting from the coarse grades with the finer grades. Sanding sealer was later applied to the sanded mask to seal the pore surfaces and the carved mask followed with wax polish (Fig., 16c).

Fig., 16a: Corel draw rendition of Mask

Fig., 16b: Rhino rendition of Mask

Fig., 16c: Final work of Mask

Source: *from authors*

Experiment V: The wooden comb

The traditional wooden comb is one of the traditional wooden artefacts which signify the beauty of the black woman (Fig., 17a) usually produced from soft woods like Sese, Cedar and Afromosia. This artefact is used as a wall hanging and it can be placed in the living room or the bedroom. The sketched, designed comb (Fig., 17a & 17b) was transferred onto a laminated bamboo board measuring 30cm x 15cm x 2 cm made out of two year old culm which exhibits the softness properties attributed to the soft woods mentioned above. This was done by pasting the sketched paper on the laminated bamboo board. The design outline was then cut with a narrow band saw and the human figure on top of the comb (Fig., 17b), curved with chisels and gouges. The dents in the comb were then removed and smoothened using the flat file and later sanded with various grades of sand paper. Few cracks which developed due to the Harmattan

season were glued mixed with smooth sawdust and applied to the affected areas and later sanded to seal those openings on the work surface. The pore spaces of the comb surface were sealed with the sanding sealer and finally fixed with mansion polish and followed by neutral polish (Fig., 17c).

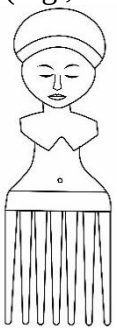

Fig., 17a: Corel draw rendition of Comb

Fig., 17b: Rhino rendition of Comb

Fig., 17c: Final draw of Comb

Source: *from Authors*

RESULTS AND DISCUSSION

Based on the results of the above experiments and the growing demand for more biodegradable and environmentally friendly products, the innovative utilization of bamboo as a substitute to conversional wood species seems to be an ideal option for traditional carving in Ghana. Potent, selective bamboo species processed into an environmentally high performance composite material, can be fabricated into laminated boards for varied furniture and craft products. The characteristic or the physical and mechanical qualities exhibited by the end products executed in this study with fabricated laminated bamboo lumber show a wide range of strength and stiffness properties comparable to that of wood. However, per the initial experiments on bamboo exposure to environmental conditions, untreated bamboo deteriorates at a faster rate and therefore becomes advisable to treat bamboo properly before using. As observed, Bambusa vulgaris has compact grains, which make it very strong and less resistant to terminates attack when chemically treated. Preservation therefore extends its life span, maintain its quality and increase durability if care is taken to choose the right type of bamboo culm.

One major advantage of bamboo is its ability to allow itself to be worked on with simple hand tools. Comparing the grains of bamboo with Mahogany, indicate a stronger bamboo compactness and durability that gives a better finishing surface (Table1). This is because the grains of bamboo runs in the same direction and the durability of the culms make carving along the grains or against the grains easier than wood. For a good carving experience on laminated bamboo, carving tools must be well sharpened intermittently as they turn to dull quickly when in frequent use. This is due to fibre strength and therefore exerting excessive pressure with the gouges and chisels via the mallet when carving may cause cracks and slight openings in the laminated bamboo. The laminated bamboo may also split open if the carving is done in the dry season as the weather adversely affect it. For less pressure work as demonstrated in the experiments, laminated bamboo lumber made from a year old bamboo has the softness properties that mahogany has and can be used to carve traditional artefacts which require lumber softness.

It was noticed that the wettability of bamboo has a significant influence on adhesion and other related properties (Kumar et al. 1994) and therefore in producing laminated bamboo lumber for carving, the inner and outer surface layers of bamboo strips contain wax, silica, starch and

sugars which do prevent adhesion must be eliminated by boiled in a solution of boric acid or lime (Rittironk et al, 2008, & Sulastiningsih et al, 2009).

CONCLUSIONS

Carvings produced out of the laminated bamboo lumber affirms the strength and stiffness of bamboo as comparative material to that of wood, making bamboo capable of replacing wood for structural applications from a sculpting perspective. The strength-to-weight ratio of laminated bamboo lumber is far better than timber, having a very efficient sculpting capability. This study proves that a simplified appropriate technological approach can lead to the fabrication of a strong lumber for carving. The implication of this simple technology, makes it practically adoptable for traditional carvers in the carving business. Such fabrication, and use can eventually reduce the dependency on conventional wood species. Additionally, laminated bamboo usage in this study has shown a high potential and success of minimizing sculptural waste though laminated bamboo products, often seems to exceed slightly the cost of domestic hardwoods processing approach. However, this simple, sustainable approach in bamboo lumber fabrication, retains favourably the structural performance of the final carved product. Further research on the fabrication approach presented would go a long way to help traditional carvers. Regardless of the fact that the anticipated approach was successful, application of diverse arrangement of glued strips of bamboo and varied pressure applied to the layers should be explored extensively to improve upon its effect on strength properties.

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