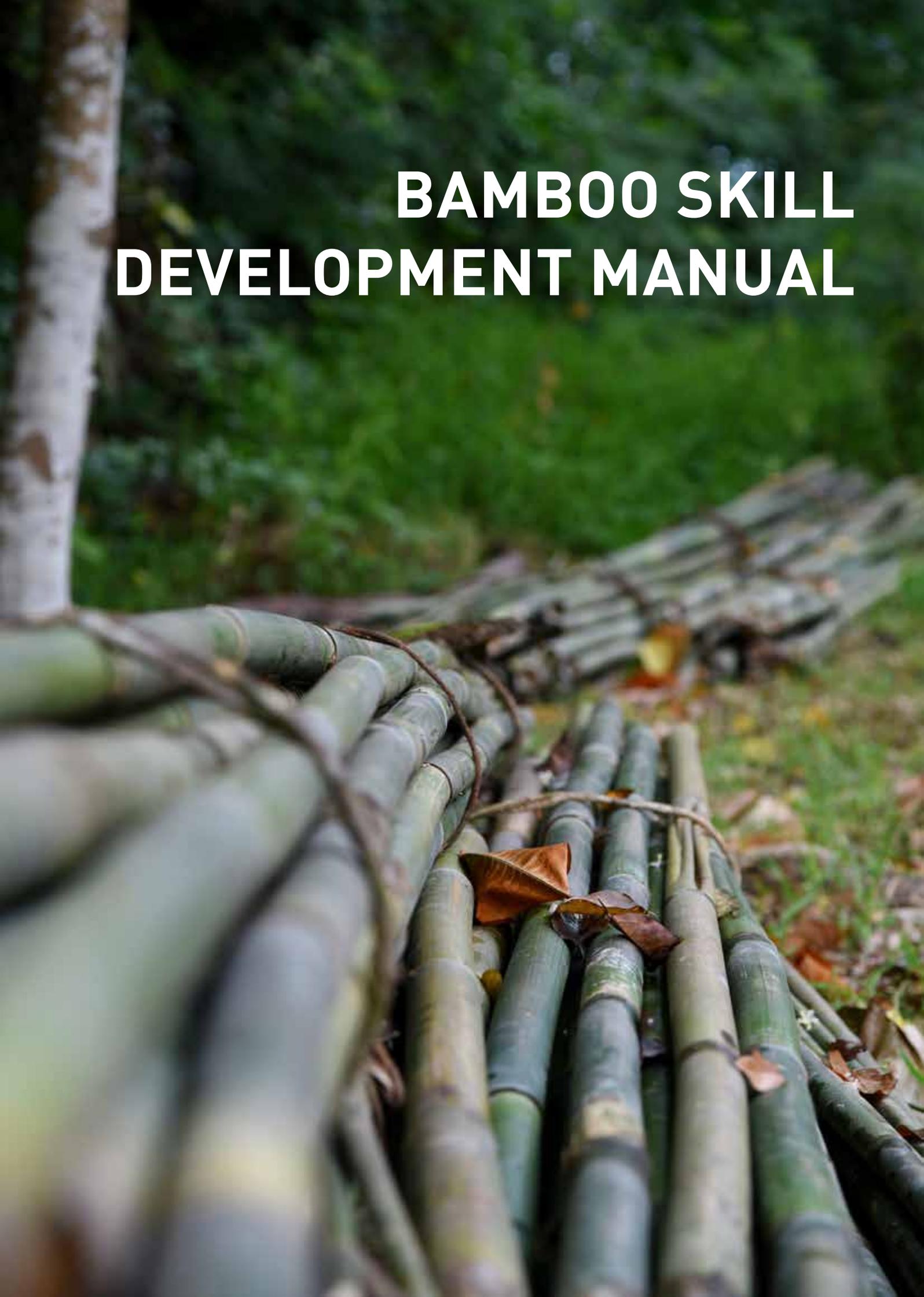


# **BAMBOO SKILL DEVELOPMENT MANUAL**



The Department of Industry in Vanuatu, with its implementing partners, the China National Bamboo Research Center and United Nations Industrial Development Organization, held a Bamboo Skill Development Workshop in Vanuatu on the island of Espirito Santo.

**Contributions:**

Mr. Weiren Zeng, a sculpture artist from China and from Germany, Mr. Jorg Stamm, an experienced bamboo / wood technician from former UNIDO Bamboo activities, performed a “hands on” furniture making workshop and trained the bamboo supply chain, preservation and quality grading procedures. The event was documented by the photographer Yvonne Fries and the text written by Mr. Stamm. The final editing and layout was prepared by Mr. Munir Vahanvati, an Australian/Indian bamboo architect, entrepreneur and co-founder of Giant Grass.

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# FOREWORD

The Ministry of Industry on behalf of the Government of Vanuatu is pleased to offer this Bamboo Skill Development Manual, as baseline for the development of bamboo handicrafts and small-scale industries in Vanuatu.

All the Islands of Vanuatu count on a collection of different bamboo species, which are part of the cultural heritage and often used in ceremonial events, household items, construction of small houses and even the bigger Nakamal Community Centers. Bamboo is in the heart of our culture and traditional woven mats represent certain clans and village traditions.

Bringing bamboo elements into modern construction requires reliable preservation methods and technical joinery, in order to guarantee stability during earthquake and hurricanes. The seasoned techniques discussed in this manual lay the foundation to include bamboo into the village economy and even into construction projects in the tourism industry in form of bungalows and restaurants with a typical flair of Vanuatu cultural heritage. Bamboo offers also the possibility of a stylish and contemporary expression in arts and architecture, yet always highlighting natural beauty and simplicity.

It will take some time to achieve design excellence and receive international recognition, but the door is open. Farmers, craftsmen, architects, investors and politicians are invited to take on this new perspective. The evolving tourism market will also appreciate local products.

This bamboo manual resembles decades of experience and seasoned bamboo treatment and building skills. There are many other ways to work with bamboo; this is just our special selection of techniques and models that would apply perfectly to the situation in Vanuatu. This inspiring manual is just the beginning; please feel free to write the next chapter in Vanuatu's history.





1

# BAMBOO AS A RESOURCE

# 1. BAMBOO AS A RESOURCE

Bamboo is a generic word for about 1500 slightly different mostly woody grasses in the tropics and subtropics, some of them tall as a church tower, others small enough to put it in a flowerpot. To the gardeners it's an evergreen plant, giving a nice green color to the leafless, grey and dark winters in the northern hemispheres. To the fashion designer it's a fancy cotton replacement for fabrics, for the industrial engineer it's the organic replacement of glass fiber in plastic composites for car parts and airplanes similar to its high tech cousin the carbon fiber. Architects appreciate the organic version of lightweight structures and the sympathetic golden color of its natural skin.

## 1.1 LOCAL CONTEXT

The geographical distribution of bamboo species is not always due to natural propagation, or through birds or ocean currents. Sometimes they are spread intentionally through migrating cultures, like being part of an agricultural tool kit. We don't know much about the wave of Melanesian settlements, but anthropologists agree that about 27,000 years ago they arrived at the Solomon Islands and moved further east by island hopping. On Vanuatu we lack archeological proof about their early arrival, although they may have already used bamboo rafts. When the Polynesian "Lapita" culture spread on canoes with outriggers throughout the South Pacific, 3300 years ago, they settled in Vanuatu on a little island in front of Espirito Santo. They introduced not only ceramic pottery to Melanesia, but also yams, coconut and taro agriculture to the new islands and they brought several bamboo plants with them. These included the giant *Dendrocalamus Asper* for repair of outriggers, or the very thin ones to make arrows, or *Gigantochloa apus* for ropes or baskets.



Traditional woven bamboo mat in Vanuatu. (Photo: YF)

In spite of having a bunch of positive attributes in its overall family, the individual bamboo pole does not represent all of the properties in one species alone. Some of the outstanding qualities highlighted by the media, like being the fastest growing plant on earth, a CO<sup>2</sup> sequestering wonder grass or being hard as steel can be misleading information taken out of its context. Nevertheless, the popularity of bamboo as a sustainable material has created market opportunities, which we can capitalize on.

Bamboo belongs to the grass family and evolved over 50 million years and adapted to the different locations. Once the root system is established (6-8 Years) the bamboo culms grow relatively fast. The new shoots are rich in protein and eatable at young stage. For the first 1-2 weeks when still underground, they are odorless and have a sweet taste. When older they are bitter, due to presence of toxic cyanogenic glycosides, and need to be cooked. Later the stem emerges with growth rates of several inches per day, growing up to its full length within 6-12 months. After the leaves are fully emerged, the bamboo culm starts solidifying and incorporates minerals over the next 5 to 6 years. An adult bamboo plant also produces a lot of starch, which feeds the fast growth of the emerging shoots, just like elder brothers take care of the kids. After becoming mature in 3-5 years they are ready for harvest. The term “culm” is used for a green and growing stem, while the harvested “pole” is becomes yellow within a month of drying. After 7-8 years the culm is so saturated with minerals that the circulation of sap comes to a halt and the culm dies. Bamboo should be harvested before it degenerates, but should have the necessary age to be hard and mature.

## 1.2 LOCAL BAMBOO TRADITION

There is a strong cultural awareness about practical and economic benefits of using certain native bamboos in Vanuatu. This is applied not only to make woven walls of their houses, but also used for musical instruments like flutes. The woven bamboo mats are present on all islands of Vanuatu and display a variety of traditional patterns and cultural heritage, which has attracted attention of international institutions.

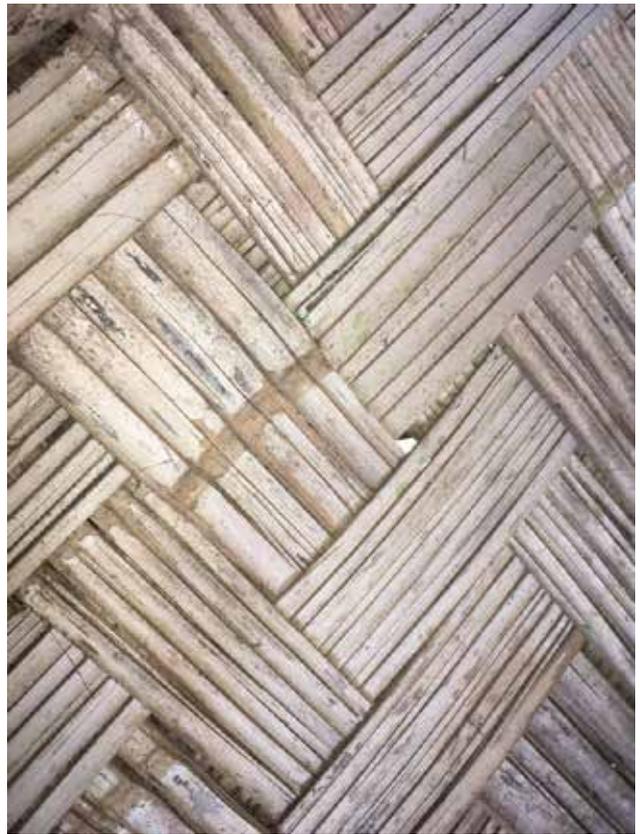
The House of Chiefs in Port Vila use colored bamboo wall mats from all island to represent the unity of their culture and the importance of customs. The “Nakamal” is a traditional (mens) house in every



Traditional Nakamal building (Photo: JS)



Inside of Nakamal (Photo: JS)



Weaving pattern in Nakamal (Photo: JS)

village and uses tree trunks for the primary structure, bamboo poles for rafters, Natangura palm fronds for the thatched roof and woven bamboo mats for the walls.

Also private homes are traditionally build from Wood, Bamboo and Natangura. Nevertheless there is a strong tendency to build cement block houses with corrugated metal roof, expressing the welfare of the owner. Bamboo houses tend to be associated with poverty, so it is our time now to show alternatives by designing spectacular buildings, in order to highlight the market potential of this widely spread resource.



Traditional house made from bamboo (Photo: JS)

## 1.3 BAMBOO SPECIES AND AVAILABILITY

After traveling to the islands of Santo, Alfa, Port Vila and Malekula, approximately nine Bamboo species have been identified, with substantial quantity and relative proximity to road infrastructure.

Some bamboo species are native to the islands and can be found anywhere in the jungle or on the mountains, especially close to rivers. The most common bamboo species found in Vanuatu include:

### DENDRACALAMUS GIGANTEUS

- The biggest Bamboo pole found on the island (20-30 cm in diameter and 20-30 meters length) is *Dendracalamus giganteus*. This bamboo is a subtropical species, found in India and Sri Lanka, where it has to withstand long dry seasons. It must have come through early settlement to the islands. Its huge volume and waxy skin offer good floating abilities.
- Its tropical cousin *Dendrocalthus asper*, the giant bamboo used for outriggers and construction throughout the Malayan/Indonesian archipelago.
- The giant bamboo from the highlands of Santo is good for buckets, and perfect for split production for furniture and laminates. For construction purposes it's rather too big and does not have a good length/strength ratio.
- We didn't find *Dendrocalthus asper* around Luganville, (although mentioned in Mr. Ding's report as present on the islands).



*Dendracalamus giganteus* (Photo: YF)

## SCHYZOSTACHYUM SPP

- A smaller native bamboo that is present widely is probably *Schyzostachyum* spp, it very suitable for mat weaving and used for ceremonial tasks, flutes and baskets. These thin walled, weak culms are also relatively resistant against borer attacks, when harvested maturely. This species is used for ages in weaving walls and big part of the cultural heritage of the Vanuatu People.



*Schyzostachyum* spp (Photo: YF)

## BAMBUSIA VULGARIS

- The most visible, yet introduced species looks like *Bambusa vulgaris*, or could also be the quite similar, yet slightly bigger *Bambusa polymorpha*. A lot of thick old, yet unmanaged clumps are found along the roads. It's especially frequent besides the old landing strip close to Luganville and may have been planted during the war, although *Bambusa vulgaris* is reported on most pacific islands.
- These stand here have not been taken care of and first harvesting is only possible with rather radical methods of cutting (with a chainsaw) at least half of the clump and extracting the mature ones. This species is recovers easily from that "haircut" and 2 years later one can extract the other half. *Bambusa vulgaris* is present in its green and also the yellow version (*Bambusa vulgaris vittata*) on most pacific island due to its tolerance to brackish or salty groundwater and its resilience to drought, which is frequent on the porous limestone of former reefs that is a common coastal subsoil rock.



Bambusa vulgaris (Photo: YF)

Most of the land belongs to traditional families and clans and is managed by the chiefs of the village. The negotiations about the resource are done in the Nakamal.

Traditionally there is no price to such community owned bamboo poles, as they were used for rituals and generally community dwellings. But in the context of becoming a cash crop, the bamboo production can generate significant income to a village community. Nevertheless, the price has ownership (chief) and the labour cost (villagers).

- The existing resources are rather abundant for the moment and no initial expenses for plantations are needed. The bamboo in the jungle gardens are rather threatened by the fast expansion of Kava plantations, which are becoming a booming commodity and some bamboo forests are being cleared out in order to become kava fields.
- There is a need to find an appropriate price for the resource and the related labour to extract it. But for the bigger poles of 6 meter, we can assume approximately a dollar, for the owner, plus another 50 cents to a dollar to harvest it and bring it to the roadside. The price is not fixed yet and coming years will have to find a balance between offer and demand.
- The price has also to do with thickness, length, straightness, matureness, and transportability. The price should be always negotiated as delivered to the nearest road, so truck transport costs can be calculated easy.

Once there is a certain quality, awareness and local treatment, this would be a win-win situation for

everybody, as it allows to upscale production and motivates the farmers to invest into plantations. New varieties of bamboo species (*Gigantochloa atroviolecia* “Black Bamboo”, *Dendrocalamus asper* (outrigger bamboo), *Bambusa balcoa* (strong and thick walled), *Gigantochloa atter* (long and straight), *Gigantochloa latiflorus* (Big Taiwan, eatable good for splits and construction) should be introduced on the islands once the system and infrastructure has developed.



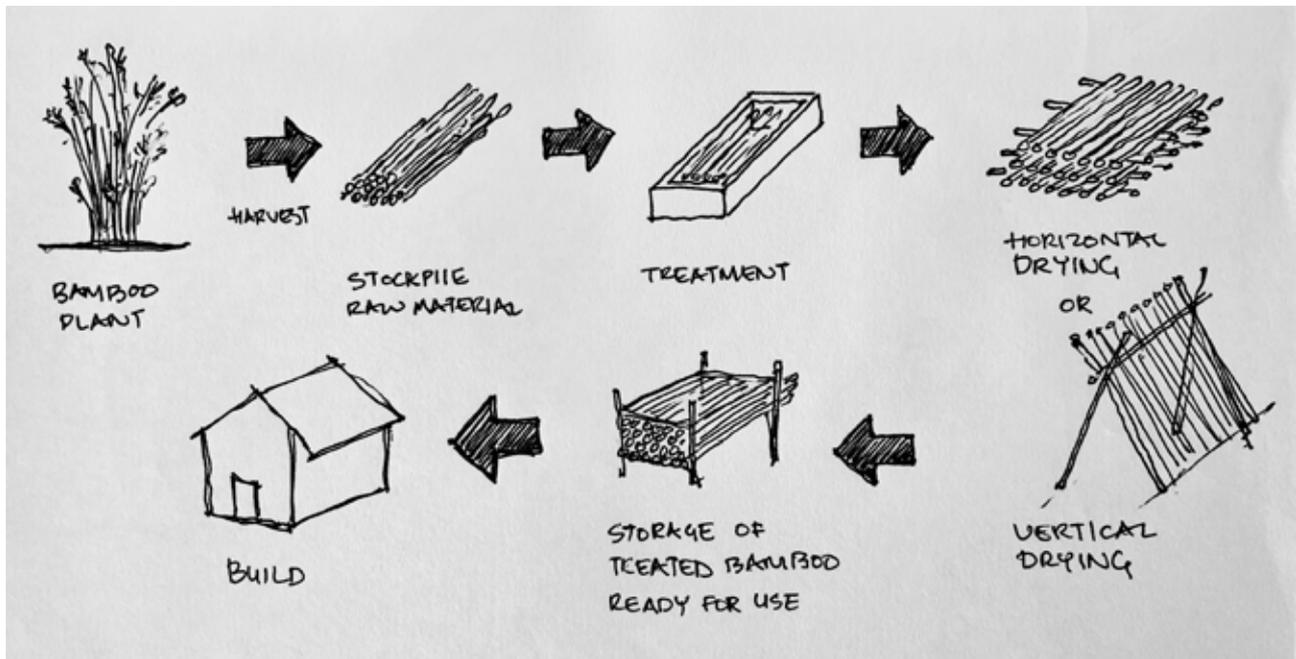
Village chief with villagers (Photo: YF)

A photograph showing two men in a bamboo forest. One man, wearing a black t-shirt and a grey cap, is in the foreground, leaning over a large bamboo stalk. Another man, wearing a yellow shirt and glasses, is behind him, also working with the bamboo. The background is filled with dense green bamboo and other vegetation. A green banner is overlaid at the bottom of the image.

# 2. PREPARATION OF RAW MATERIAL

## 2. PREPARATION OF RAW MATERIAL

For a bamboo structure or furniture to last long it is essential that appropriate harvesting and treatment procedure be followed. This is primarily to prevent against borers, which like to eat the sugary sap inside bamboo. Below is a diagram showing an overview of bamboo harvesting and treatment process. Each element is explained in detail further in the chapter.



Bamboo harvesting and treatment process map (Photo: MV)

### 2.1 BAMBOO SELECTION AND HARVESTING

The local Chief has to secure a harvesting sequence of his clumps. Only the mature culms should be cut and extracted, while the younger ones should be left for later. Bamboo culms that are older than 3-4 years are considered mature for harvesting. One way to tell them apart is a transition in color from deep green to lighter green on the stem and they are generally covered by moss and lichen. In a properly managed forests culms are generally numbered by the year that the shoot.

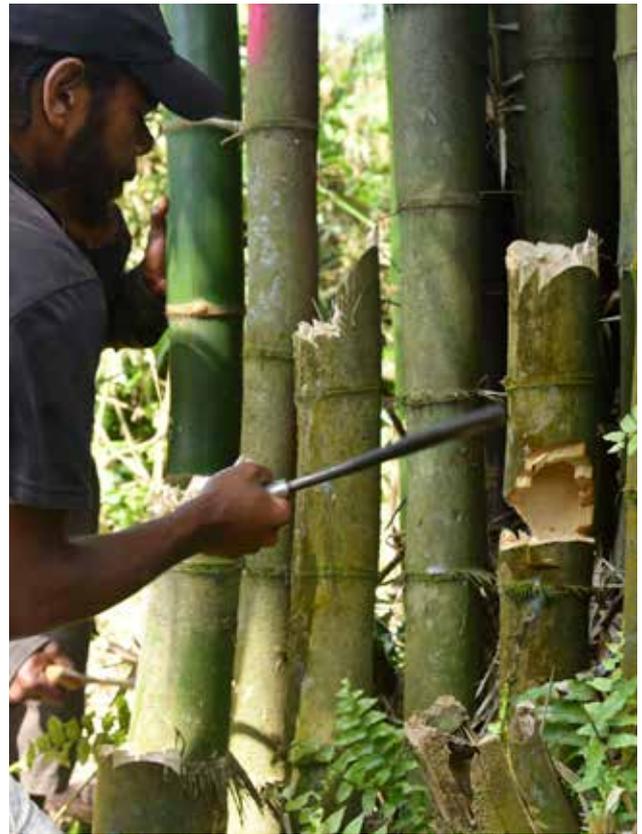
This knowledge has to become every ones criteria for harvesting, its absolutely basic to the development of bamboo business: the raw material must be mature and the occasionally harvested younger culms (1-2 yr) must not be used for construction, but chipped and mulched, in order to avoid weak culms getting into the production chain.

Bamboo poles can be harvested using a variety of tools depending on the quantity required and tools available. Most common method in villages is to use a large machete to cut bamboo poles. Chainsaws can also be used if harvesting in large quantity or clearing a large part of a clump to speed up the process.

A proper harvesting and management of a clump will increase the bio mass and profits for the owners as years progress.



Bamboo harvesting using chainsaw (Photo: YF)



Bamboo harvesting using machette (Photo: YF)



Pulling out cut bamboo poles from a bamboo clump (Photo: YF)

## 2.2 TRANSPORT AND LOGISTICS

Transport and logistics is an important component of setting up a viable bamboo industry in any region. Bamboo poles are quite long and can require long and expensive trucks to transport. Additionally, it requires good quality roads to ensure that large trucks can use them safely. It is possible to overhang the poles over the drivers cabin and over the back, to transport them with special permits and red flags at the end.

If long bamboo poles are too expensive to transport they can be cut into shorter segments locally before transport. The exact length will depend on the use of the poles. Additionally, bamboo poles can be sliced up into splits locally, dried and bundled in packs for transport.

With increasing production and opening markets, It could be even possible to treat the bamboo splits in the village, some day the added value will arrive at the source. Such packs of treated splits could be transported by the villagers in their own, smaller cars and go directly to the markets.



Bamboo being transported on the back of a pickup truck (Photo: JS)



Poor quality roads can make bamboo transport difficult during rainy season (Photo: JS)

## 2.3 TREATMENT AND PRESERVATION

Once the bamboo poles are harvested, they should be treated while they are still green and not completely dried out. Most of the giant bamboo species are suitable as construction material, but they should be treated with bitter salts like Boric Acid and Borax in order to withstand termites and wood eating beetles. These chemicals have been used reliably for more than 25 years for at least a dozen

tropical bamboo species. Boron is considered in Germany as the environmentally cleanest method.

There are other treatment methods, like petrochemical treatment with Piretroids, which are artificial copies of the insect repellent Camphor tree (Deltamethrine, Perimetricin, Dimethrin), usually dispersed by tenside in water. These methods are widely used in handicrafts and bamboo furniture in Asia and most piretroids are accepted on European and american markets.

As bamboo has an almost impenetrable skin on the outside, the difficulty consists in getting the liquids into the tissue, so drilling and full submersion is the best way to go. But some furniture use bamboo poles whose skin has been removed manually, these ones could be painted with such wood preservative liquids, especially if the chemical is designed for deep penetration.

There are also many wood preservatives on the market that are not clearly labeled and are not user-friendly nor indoor rated. Most chemical brands on the market don't reveal their formula and should not be used without deeper understanding. Anyway the application of such ready mixes in big scale operations become rather expensive and can't compete with the rather uncomplicated, cheap and water based borax diffusion.



## Technical information

Borax and Boric Acid powder is easily available in the market. It has an export sale price of approximately 1 dollar per kilogram, if buying a container in China, Chile or Turkey. Boron as agricultural imports in bigger quantities can receive tax favors, but even if the retail price will be 2 or 3 times the cost, it's still the cheapest method. One 6 meter bamboo pole will consume approximately 300-500 grams per culm, so the overall cost for the preservation agent alone should not be more than half a Dollar. The labour cost of the process is a more tricky part, as it depends on local wages, machine investment (power washers for cleaning, electric winch for taking out the poles, Drying kilns, versus cleaning and carrying the poles by hand, or rather time intensive natural air drying). Each entrepreneur has to find his way to make a living and transfer the costs to the client.

As we are focussing here on boron salts as non toxic and user-friendly method, we have basically two methods for treatment:

- The horizontal dip diffusion; and
- The vertical diffusion.

Both methods use a 5 % boron solution in water, which means that one bag of 25 kg borax powder/granulate and one bag of 25 kg boric acid granulate is mixed into one ton (same as one cubic meter of water).

The result of mixing 40% boric acid and 60% sodium tetrahydrate is a ph neutral mix that is easily absorbed and it's soluble up to 8-9% in ambient cold water. For our practical approach we can either work 50/50, meaning 25kg/25kg per 1000 liters, or 1/3 Boric acid (25 kg) + 2/3 Borax (50kg) for 1500 liters.

The long term chemical reaction creates octoborate, which is also widely available as readymix

brand name “Timbor”, yet the price tag is tenfold and its still the same octoborate. Timbor recommends a 10% application (1kg in 10 liters of water). But this brand is used as a paintable solution to be brushed on the surface of wood, soaking into the tissue. With our bamboo skin being impenetrable and the bamboo not having radial pores, this “outside only” application will not work. We need drill a hole lengthwise and dip the pole into the Boron Water solution, to be absorbed in the bamboo wall tissue from the inside. We can dilute the solution to 4 to 5% (40 to 50kg in 1 cubic meter of water) as it will have a longer contact time of 5 days.

The treatment is based on osmotic diffusion, it means the process will only working as long as the cell membrane is still alive, or the bamboo is still a bit greenish. Boron is incorporated into the woody tissue of the bamboo wall. A 3kg retention of boron equivalent per cubic meter is the minimum defined by the american code for wood treatment against borers and termites. Some tests reveal that 4 kg/m<sup>3</sup> gives a total guaranty even against the most aggressive “Taiwan” termites. A 5% solution in water will achieve this concentration after 3-4 days in 18-20°C cold water, or 2 hours in 50-60°C hot water.

Boron is soluble in water, so the lumber should not be exposed to permanent humidity, otherwise it could leach out, over some time. But bamboo has a natural skin that avoids such leaching through rain. Some commercial wood preservation ready mixed salts are as CopperChromeBoron (CCB). Chrome fixes the boron against leaching and the copper sulfate acts as prevention of fungus, but these two agents are highly toxic and not the product you want to use in farming areas, nor with farmers / workers who are unaware of the consequences in handling toxic substances without gloves and eye protection. The usual borax/boric acid mix is not toxic to contact, unless its swallowed. Boron salts in small concentrations are even medicinal against skin fungus and are used in eye drops. The use of gloves and eye protection is recommended on the bag, but in our situation it’s unrealistic on the long run. So it is better to use rather safe methods and give a profound introduction about real dangers and hidden threats.

## **HORIZONTAL DIP DIFFUSION METHOD**

Horizontal dip diffusion is either possible in ambient temperature “cold” water tanks, where it requires a 5-day submersion at 4-5% concentration. Even a day less will not compromise the minimum take up; it rather depends on the activity of the cell wall. If the bamboo pole is already drying, it is necessary to add one or two days or increase the temperature. The poles have to be drilled lengthwise in order to “drown” into the solution.

Dipp diffusion in hot water, with temperatures somewhere between 50 and 70°C increases the osmotic process significantly. Even two or 3 hours are usually enough (tested with tropical bamboos like *Guadua angustifolia* or *Dendrocalamus asper*) to reach the necessary incorporation of boron salts in the cells. Nevertheless there are two categories, tropical and subtropical bamboo species, which have different properties and different wax/oil content and may react different to boron salt uptake.



Punching hole through the bamboo nodes using a reo bar (Photo: YF)



Soaking bamboo poles in the solution of boric acid and borax (Photo: YF)



Heating the steel tank to accelerate the dip diffusion process (Photo: YF)



## Technical information

Subtropical bamboos are easy to treat by heat, either fire or boiling water, as they sweat out a wax/oil which can be wiped of and polished nicely. The typical heat treatment of Chinese (Mao Tzu) bamboo species does not necessarily work on tropical species and from our experience boron soaking is the best insect treatment.

The tank is usually a metal tank with a fire under it, fueled with bamboo left overs. Two or three cycles per day are feasible, usually the last one stays in over night with the slowly extinguishing fire.

A one meter deep, 2 meter wide and 12.5 meter long tank (1 x 2 x 12 meter tank made from concrete blocks requires at least 3000 usd, but can soak 100 poles of 12 meters per batch per week. It also would require at least be filled half, which means a borax investment up front of 13 cubic meter of solution and 13 sacks of borax and 13 of boric acid (both come in 25 kg bags, which makes it easy to count the refill). A metal tank can be made from an old oil tank, or just welding 3 mm steel sheets onto a metal frame.

## VERTICAL SAP DIFFUSION

Vertical Sap Diffusion (VSD) was developed by the Environmental Bamboo Foundation with professional support of Dr. Walter Liese, from Wood Institute of Hamburg University. This process uses the pole itself as a treatment tank, like a “bottle”, only the drilling process has to be done from the upper side, leaving the bottom diaphragm intact. This way the upstanding pole can be filled with a hose or a bucket, gradually drowning chamber by chamber. After 5 days of soaking into the tissue,



Bamboo poles arranged at an angle (Photo: YF)



Pouring boron solution in bamboo (Photo: YF)

the borax will penetrate all cell walls, even the thicker ones on the bottom. Then the pole is lifted onto a barrel and with a hammer the bottom diaphragm is punched, recovering most of the liquid in the barrel.

This method is practical in small-scale operations, but if the bamboo poles have cracks or borer holes they cannot hold the water. Borer holes can be sealed with toothpicks, but this can be sometimes time consuming. It is also important not to throw the poles around as this usually causes cracks.



### **Technical information**

The capital investment in this method is low, as the second hand oil barrels / 200-liter drums are easily and everywhere available for 20 to 30 dollars (Vanuatu 60-70 Australian dollars). So this method is perfectly applicable on village level and neither electricity nor machines are needed.

In VSD the poles don't have to be "vertical", a little hill or a second story balcony are usually enough to lean the poles in a 30-40 degree angle, that allows the air bubbles to rise.

The use of small submergible electric pumps ("bottle" pumps at the gardening store) help a lot with the refueling from the bottom barrel into the funnel on top of the new poles. But the process can also be done with buckets.

Boron is a colorless salt, but its presence in the tissue can be traced by rubbing fresh cucumber or turmeric on the bamboo. The usually yellow color turns orange if boron is present in the tissue. Precise determination of concentration can be done only in a laboratory with microscopes or a special device for molecular or mineral determination.

## **2.4 BLEACHING**

People expect bamboo poles to be shiny yellow. To achieve this colour bamboo needs to be exposed to the sun, otherwise it will dry as a unattractive light green colour. Torching or dyes can achieve deeper brown tones in at the bamboo if required.

After being pulled out of the tank and piled up at a drip of area, bamboo poles should be exposed to the sun in order to bleach the green chlorophyll and turn the color into the typical golden yellow shine, which is associated with bamboo.

The best way is standing the poles for 2-4 weeks against "A- Frames", allowing the UV light to hit the surface on a steep angle. The poles should be turned every other day to achieve an even bleaching process that does not overheat the stems. If the poles are laid horizontal on the ground, the sun can heat up the poles causing cracks. Thinner poles with thinner walls dry faster than the thicker ones, so the poles should be graded by their natural thickness on the A-frames and monitored carefully.



Bleaching of bamboo poles on an A-frame (Photo: JS)



Blow torching bamboo poles to create a burnt effect (Photo: YF)

## 2.5 DRYING

The water content in freshly cut bamboos can be more than 150% of the dry weight. It means that one-meter of totally dried bamboo, 12 cm diameter, weighs approximately 3 kg, but the same piece freshly cut can weigh 7 or 8 kg.

A very old method of reducing that initial water content in the wall tissue (and within the “lumen”,

the empty space between the diaphragm is sometimes filled with water) is by cutting the culms at the bottom and let the rest with the leaves hanging in the bush over the next two weeks, in order to transpire that water until the leaves dry up. Meanwhile the remaining sugars within the cell wall start a fermentation process, which converts them into vinegar and makes them unattractive to borers. This natural process is a traditional bamboo treatment in many countries.

Air dried poles and boron treated bamboo can be stored for decades, there will be no change unless the bamboo is exposed to water, which can create expansion and also ideal conditions for fungus.

### **Technical information**

Drying is dying; at least the cells in the bamboo tissue dry up before their starch is being fully removed. Another effect of drying woody cells is the dimensional shrinking. Bamboo shrinks around 10% when drying up. This shrinkage is as much in diameter as in wall thickness, yet almost nothing lengthwise. That is why bamboo poles should be worked lengthwise.

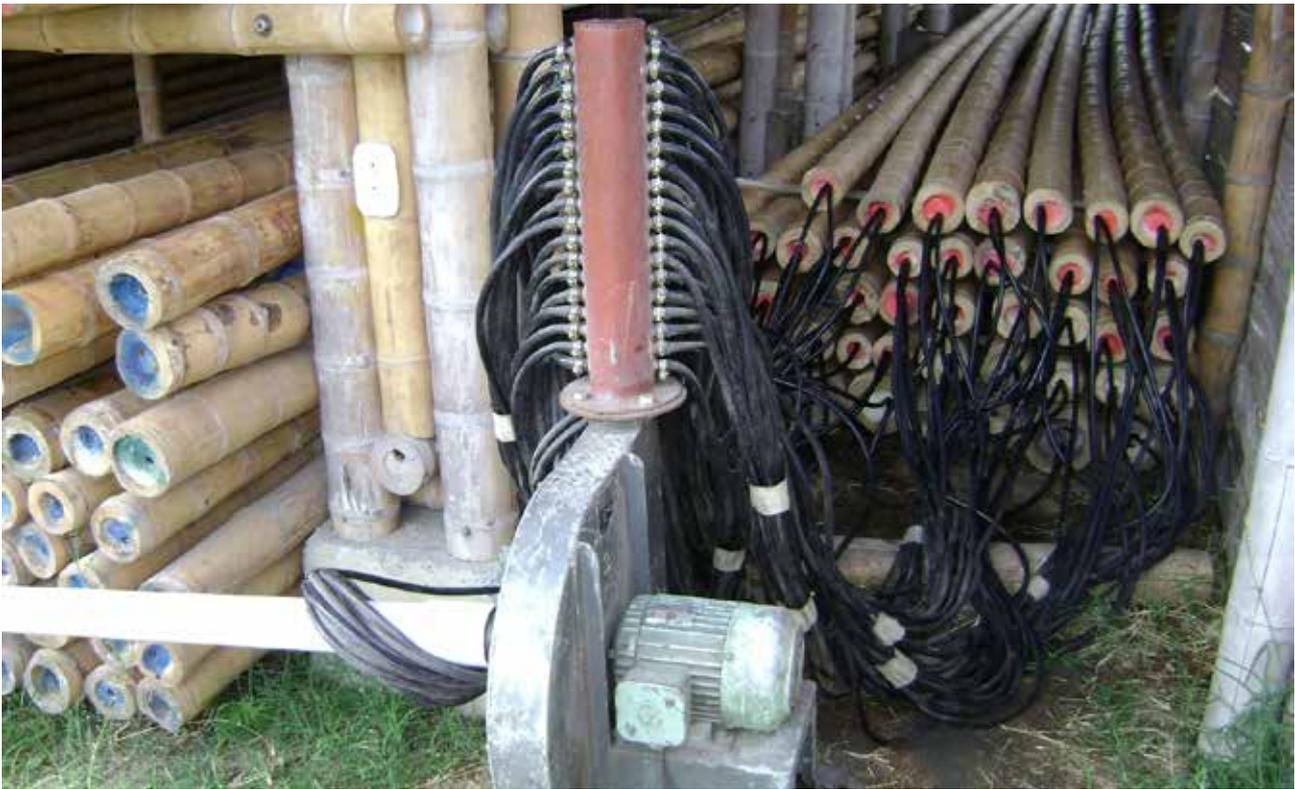
The overall dimensional change is about 10%, but in case of air drying the moisture content will stabilize somewhere at 15%. So, a 12 cm pole will shrink during this process approximately 6-8 mm, depending on the maturity. Young poles generally develop long cracks during this drying period. Mature bamboos that dry slowly will not crack.

The hollow chamber also shrinks, so if one does cement mortar injection when the poles are wet, the compact cement block will not allow it to shrink and even the mature bamboo will crack. This technique is also called grouting and should be done when the bamboo has reached 20-22%, so the cement block will fit tight but not cause cracks.

The best way to dry bamboo is under a sheltered roof with free flowing air. The natural air drying process generally takes 2-4 months, depending on the weather. To dry the bamboo should be stacked in horizontal piles which cross over each other to ensure there is enough gap for airflow.



Bamboo pole drying under shelter (Photo: JS)



Drying bamboo poles with hot air can decrease the drying time significantly (Photo: JS)

## 2.6 GRADING

Besides the previous selection process of mature poles in the forest, there is a quality grading process after the treatment. This is rather a grading process that separates the poles according to their diameter, but also straightness.

After being bleached in the sun, the poles should be stored under a roof with well-ventilated conditions and natural airflow.

### **Technical information**

The best way is to build a rack with two big divisions, left for the curved poles and right for the straight ones.

The rack should be at least three or four levels with some 50 cm in between, so the thicker poles are stored on the bottom and the thinner ones further up, as this is natural to the workers.

The space in between the layers of culms should have splits as spacers to ensure good airflow and moisture extraction.

After this shelf is full and the bamboo has reached some 20-22% humidity it can be relocated to stakes without separating splits in between. These piles should still have a roof with wide overhangs and rest on blocks, at least 12 cm separation from the ground.

These stakes should be graded according to their diameter in 2 cm thickness steps: 2-4cm, 4-6cm, 6-8cm, 8-10cm, 10-12cm, 12-14 cm, etc.



Grading bamboo poles by painting different colours on the end (Photo: JS)

## 2.7 STORAGE

Bamboo can be stored as long as it is under a well-ventilated roof, ideally with big overhangs.

Bamboo poles should not lie on the ground, as moisture uptake through the soil occurs. Some companies store the poles standing, in order to make more use of their storage.

The storage area should have boxes for the different diameters, lengths and curviness, as outlined above. Some US companies have established their own grading scheme and apply a color coding at the thick end diameter of the poles: red dots for 3-4 inch, blue for 4-5 inch, green for 5-6 inch, etc. these markers help to reorganize the poles after shipping. Some animals like lizards, spiders, rats and snakes love those hollow tubes and hide in there, so piles have to be fumigated, usually with Methyl Bromide, before shipping.



### Technical information

Indefinite storage means also a lot of money sitting there. The added value chain for bamboo poles can reach roughly 2 dollars per meter for 4 to 6 inch poles. That means a standard 6 meter pole can absorb working capital of up to 10 -12 dollars in cost build up between all the above mentioned steps. To prepare 1000 big poles for a container your investment is going to be approximately 10,000 Dollars. Sales price could be 50% more.

Smaller bamboos or 3 - 4m and of 2 inches in diameter can easily reach costs of 3 - 4 dollars, depending on the quality and finishing. Your national sales price could be 50 % more to a client ordering good quantity. But overseas sales prices can even be 100 or 150% on top of the wholesale price called FoB (Free on board), all depending on the shipping freight costs and the brand name of the retailer.



Long poles can be stored at an angle under a large shed (Photo: MV)



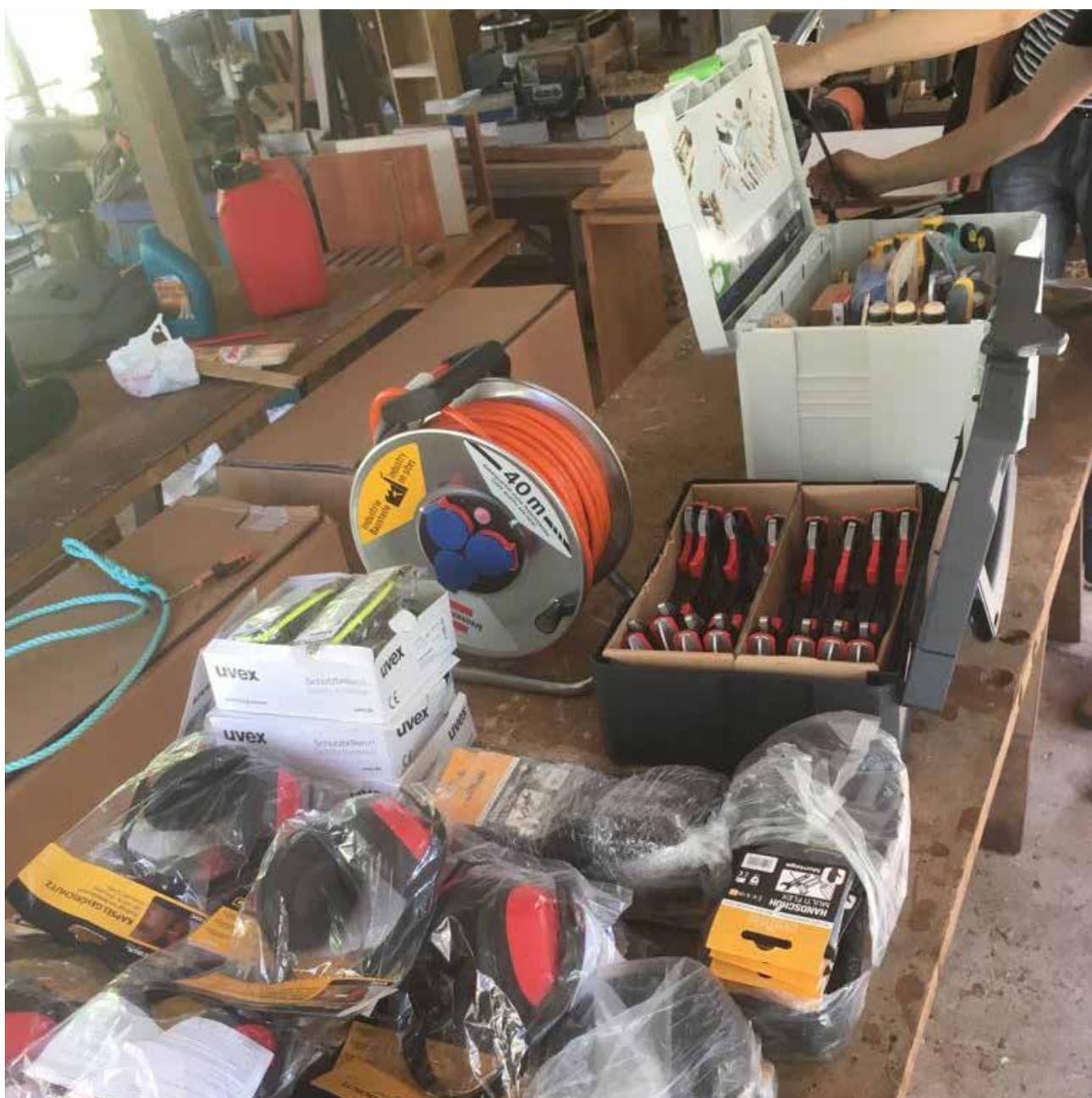
3

TOOLS AND  
EQUIPMENT

### 3.TOOLS AND EQUIPMENT

Working with bamboo does not require significant investment in tools and heavy machinery. Traditionally, most cultures can do majority of the work using a large knife. In Vanuatu, the villagers primarily use a knife/machete to cut, carve and split bamboo. Although, this is sufficient to do most of the work some specific tools can help speed up the work and expand the range of activities that can be carried out.

Bamboo construction can be done primarily with hand tools and without the need for major power tools. Some power tools like a corded or cordless drill can make things quicker. Below is a list for key tools required for working with bamboo, this list is not exhaustive and provides information on some of the specific tools. Traditional woodworking and construction tools will also be required if building structures.



Bamboo toolkit donated to villagers including safety equipment (Photo:JS)

## HANDSAW

Bamboo is fairly easy to cut with a handsaw and it also provides a good finish. In villages a normal carpentry saw is used to cut bamboo, although this saw can do the job there are better alternatives that are more suitable in working with bamboo.

Specifically pull saws are excellent at cutting bamboo. They have bidirectional teeth and come in various teeth sizes from large to fine, allowing for fast cut to finish cuts. Although these are slightly more expensive than regular carpentry saws, they are made from high quality steel and last much longer than regular saws. Unlike the traditional carpentry saws that cut on the push the pull saws cut on the pull. This makes them more efficient and it is less tiring on the hands.



Cutting bamboo using a traditional saw (Photo: YF) Commonly used carpentry saw (Photo: MV)



Pull saws make cutting bamboo a breeze with different teeth sizes (Photo: MV)

**Tip: Rotate the bamboo slowly while cutting and cut using the outside edge to get a fine cut without splitting any fibers.**

## BAMBOO SPLITTER

Bamboo splitter is a tool specific to building with bamboo and is used to make bamboo strips from circular bamboo poles. It has a steel ring in the middle, which is segmented with steel blades and has handles for holding. The circle can be divided into 3,4,5,6,8 or 10 parts depending on the width of strips required.



Types of bamboo splitters with 5, 6, 7 and 8 parts (Photo: XX)



Aligning splitter to the centre of the bamboo pole (Photo: MV)



Using bamboo splitter to make bamboo strips from round bamboo (Photo: MV)

**Tip: For long bamboo poles more than 1.5m long the splitter can be used by keeping the bamboo poles at an angle and banging it against a big rock or a brick wall.**

To use the splitter align the steel ring on the center of bamboo pole as shown in the photo. Tap gently with a hammer or on the ground to ensure that the blades make a cut on the top of the pole. Once the splitter is embedded in the bamboo pole, one can use the handles and tap the bamboo on the ground to push the splitter through. This is quite easy as the fibers in the bamboo run along the length. This method produces fairly straight strips with minimal cost. Different types of splitters can be used depending on the width of the strips required and the diameter of the bamboo pole.



Using a twin blade table saw to make bamboo splits (Photo: JS)



Long bamboo poles can be split by keeping the poles at angle (Photo: MV)

## **BAMBOO HATCHET/MACHETE**

A bamboo hatchet or a machete is a multi purpose tool and can be used to cut bamboo poles, cut the branches from the poles, split bamboo poles in half or make bamboo strips. Additionally, it is used to remove the nodes and clean the edges of the bamboo strips that are made using the bamboo splitter.

Most traditional cultures have a large knife or machete they use to cut and carve bamboo. A bamboo hatchet made from high carbon steel is an excellent replacement for some of the local knives. It is made from high carbon steel and is extremely sharp and long lasting due to the high quality of steel.



Traditional bamboo knives (Photo: MV)



Bamboo hatchet (Photo: MV)



Bamboo hatchet can also be used to split bamboo along with a mallet (Photo: MV)



Cleaning sharp edges of bamboo strip using a bamboo hatchet (Photo: MV)

**Tip: If bamboo splitter is unavailable a bamboo hatchet can be used to make bamboo strips using a mallet.**

## MALLET

Mallet is a hammer with a soft rubber or wood head. It is generally used in conjunction with other tools like the bamboo splitter or bamboo hatchet to hit the metal tools. The rubber head ensures that the steel tools are not damaged and prolongs the life of the tool.



Wooden mallet (Photo: MV)

**Tip: Use the rubber mallet instead of a hammer in conjunction with other steel tools to extend the life of your tools.**

## CARVING KNIFE

A carving knife is a small knife used for fine work with bamboo. It can be used to make bamboo pins, shaping the fish mouth joints or other fine carving requirements. Traditionally many cultures used a small sickle shaped knife for this work. Alternatively a single edged marking knife can do a great job. The single beveled edge provides greater control and the high carbon steel makes sure the knife stays sharp for long.



Using the traditional knife to remove the outside skin of bamboo (Photo: YF)



Single bevelled bamboo carving knife (Photo: MV)



Using the carving knife to make bamboo pins (Photo: MV)

**Tip: Use the carving knife instead of a bamboo hatchet to remove sharp edges for the bamboo strips for more control and precision.**

## SCRAPER

Bamboo generally bulges on the outside near the node. A scraper is a small steel blade that is used to scrape the outside of the bamboo node. The blade is generally inserted in a piece of bamboo making it easier to hold.



Using bamboo scraper to shave the outside of bamboo node (Photo: YF)

**Tip: A powered sanding machine can also be used instead of a scraper to flatten the outside nodes of bamboo.**

## CORDED OR CORDLESS DRILL

A corded or cordless drill is one of the few power tools essential to building with bamboo. Hand drills can be used but it can take a long time to drill a hole and it is time consuming. When building a bamboo structure, a cordless drill is preferred if available as it reduces the need to run long power cords making the construction site safe.

When purchasing a cordless drill it is very important to make sure that it has enough power to drill into thick bamboo ideally. Best to go for an 18V drill with maximum amp available, ideally a drill 5 to 6amp current is preferable.

**Tip: Cordless drill also provides the flexibility of single-handed operation as the battery balances the weight. This is really useful when drilling in high places and one hand is required for stability.**



Corded drill used to drill holes (Photo: YF)

## DRILL BITS

Good quality and sharp drill bits are essential to drill good holes into bamboo. Cheap or blunt drill bits can result in holes with split fibers. High quality HSS drill bits and brad point bits are most commonly used to drill regular sized holes. They come in a variety of sizes and easily available from a regular hardware store.



HSS and Brad point drill bits (Photo: MV)

Additionally long auger bits are required when drilling through 2-3 pieces of bamboo while building a structure. Auger bits come in lengths of 15-30cm, which makes them ideal for this task. They also have a cutting edge in the front, which makes sure fibers are cut giving a fine finish. It is important to make sure the cutting edge is sharp otherwise it will result in split fibers.



Auger drill bits (Photo: MV)



Large diameter holes can be drilled with Forstner bits. They come in a variety of diameter sizes ranging from 10mm to 50mm. Forstner bits have a saw tooth cutting edge and a shaving blade making it ideal for large holes in bamboo providing a clean finish. It is also possible to use hole saws with a drill for large circular holes. The hole saws only have a cutting edge, which can make it difficult to drill in bamboos with thick diameters. Additionally, hole saws are also used for making fish mouth joints.



Forster bit set (Photo: MV)



Hole saw set (Photo: MV)

**Tip: Make sure the drill bits are kept sharp to ensure a clean hole. A blunt drill bit will result in split fibers.**

## ANGLE GRINDER

Angle grinder is a good multipurpose tool to have if power is available on the site. It is possible to use corded or cordless angle grinder. It is primarily used to cut long threaded rods and bolts while building a bamboo structure where bolting is the primary connection. It is possible to cut the metal bolts with a regular hack saw, but having an angle grinder makes the task super quick.



Angle grinder cutting a bolt (Photo: MV)

It is possible to use a range of disks with the angle grinder making it a truly versatile tool. Some of the most common disks used with an angle grinder for bamboo construction include:

- Metal cutting disk for cutting metal
- Grinding disk for grinding metal
- Wire brush disk for removing rust and paint on metal
- Flap wheel for sanding edges of bamboo
- Wood cutting disk for cutting thick branches
- Carving disk for fish mouth joints and sanding
- Photo of various angle grinder discs



Various angle grinder discs and attachments(Photo: MV)

**Tip: It is best to keep a few angle grinders handy with different disks attached, as it will save time changing disks during construction.**

## DROP SAW / MITRE SAW

A drop or mitre saw could make cutting bamboo into fixed lengths a quick process instead of a hand saw. It is especially useful for a large project where huge quantity of bamboo is required to be cut. A drop saw is widely used in woodworking and carpentry and can be found in a good hardware store.



Using a drop saw to cut bamboo poles. (Photo: YF)

**Tip: Use fine teeth blades with the drop saw for clean finish while cutting bamboo.**



# 4. BAMBOO CONSTRUCTION

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## 4.1 BAMBOO JOINERY AND DETAIL

One of the biggest challenges of building with bamboo is connecting two pieces of bamboo together. Using appropriate joinery is essential to build structures with bamboo. There are various ways of connecting bamboo. Bamboo joinery is very different from wood and other construction materials. Due to its structural anatomy, a bamboo culm should be used according to its cross section and its internode distance. The effective use of a bamboo culm is shown below.

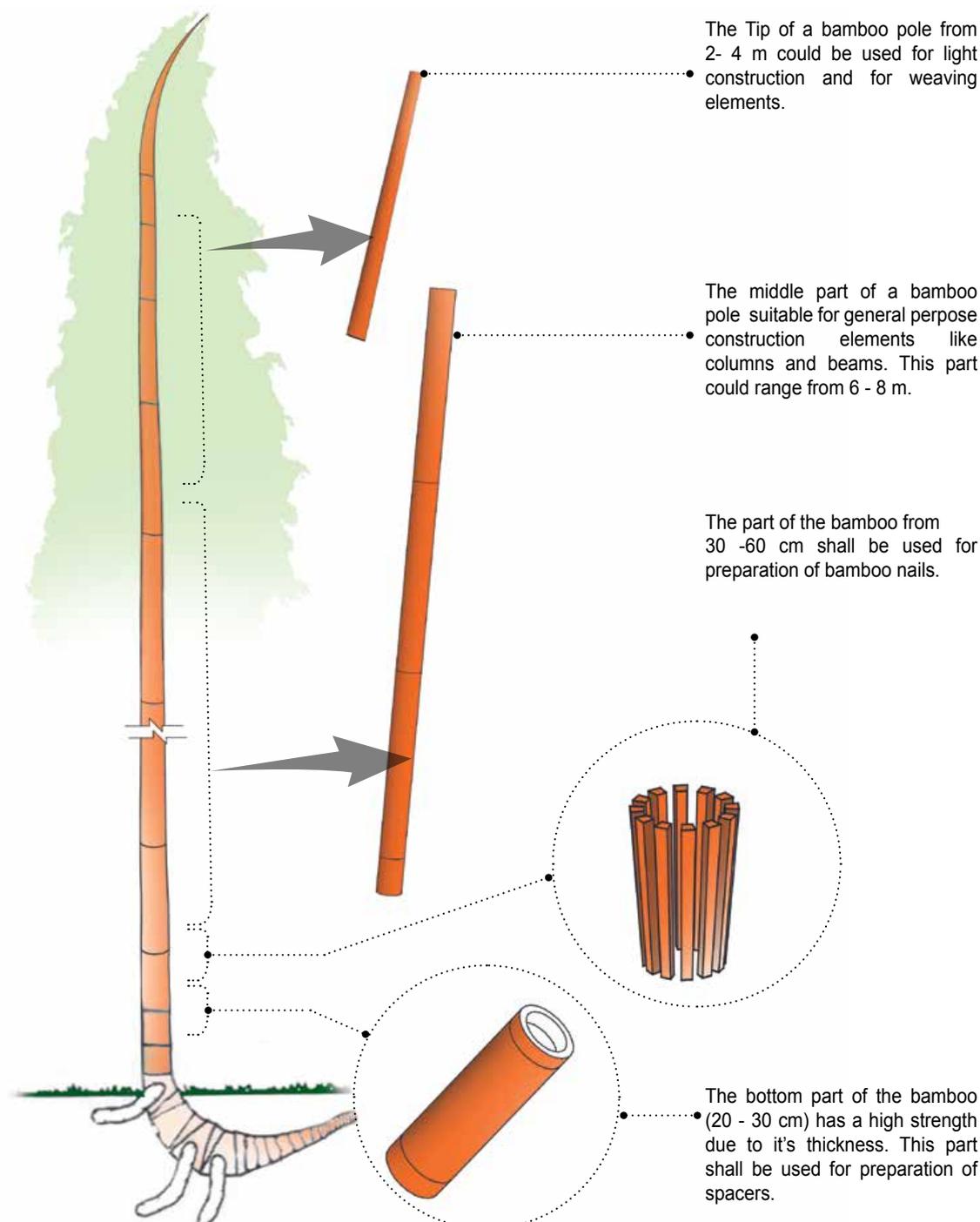


Diagram showing how different sections of bamboo can be used for construction

Source: Construction Manual Bamboo

Traditionally tying with natural fiber and using bamboo pins was the most common approach. In the 20th century Simon Velez along with Marcelo Villegas pioneered the use of steel bolts and concrete, which changed how bamboo structures are built. As part of construction workshops we have tried various connection details that can be used for bamboo construction. Some of them require fabrication of special connectors and might not be possible to implement in Vanuatu, but they have been included to provide a broader understanding and scope of what might be possible.

## LASHING AND PINNING

Traditionally lashing was the prominent form of bamboo connection. Generally natural fiber rope like sisal or palm is used for lashing but it is also possible to use polypropylene ropes. There are various types of lashing knots but the most common one include square lashing, diagonal lashing and shear lashing. Although it is possible to use lashing on its own many times it is used in combination with bamboo pins making the joints stronger.



Lashing and pinning joints (Photo: MV)

Lashing provides great flexibility in connecting bamboo but it is very time consuming and requires highly developed skill, otherwise the rope tends to get loose over a period of time. Natural fiber ropes need to be replaced every few years if they are exposed to the elements.

## STEEL BOLT

The bamboo poles are connected using threaded rod with nuts and washers at both ends. Use of steel bolts allows creating complex connections, which are not possible with lashing. Concrete is poured inside the bamboo internode for the joints that have high shear stress



Galvaised steel bolt connections (Photo: MV)

Steel bolts make building a bamboo structure much quicker than lashing. Use of bolts requires a good understanding of structural design principles and the principle of triangulation, as each joint is a pin joint. Once the structure is built it is difficult to remove and replace poles.

## HUBS

Hub connector generally consists of a central ring connector, which is connected to bamboo using a steel plate or rod. Poly pipe can be used with bamboo to create a hub connector, which is bolted in the middle. Hub connectors can also be combined with clamps as we did in the Bamboo Greenhouse.



Central hub type connectors (Photo: MV)

Hub connectors are generally used to join many pieces of bamboo in the middle. These types of connectors are useful to create geodesic dome or other geometric forms. These connectors are generally custom fabricated for specific projects and are not readily available.

## BRACKETS AND PLATES

Brackets or plates are used to connect the bamboo in the same plane and useful to build trusses or other similar structural elements. Brackets are generally L-shaped pieces made out of steel and bolted to bamboo to create 90° connections (Figure 9). Plates can be made from steel or plywood and are used to connect various bamboo poles using bolts.



Brackets and plate connectors (Photo: MV)

It is difficult to find steel brackets or plates for use with bamboo; generally they need to be custom fabricated. They are generally useful for some structural components but mainly in 2 dimensional planes.

## 4.2 BAMBOO STRUCTURES

The first 6 to 9 meters of locally harvested and boron treated *Bambusa Vulgaris* poles are suitable for civil construction of small and big houses, community centers (Nakamal) or restaurants, gazebos or tiki huts and tourist bungalows. Construction projects take time, as they need foundations, the structure itself can be built in a week or two, walls will take a bit longer. But the new structure also need a roof quite soon, otherwise the beautiful Bamboo poles are exposed to the sun and will crack, the color fades and the life span is considerably compromised.

This section identifies some of the construction opportunities in Vanuatu using locally sourced bamboo.

### CONTAINER HOUSE

This is a small structure that was built at a permaculture garden in Bali. It can be built at a beachfront hotel in Santo during a 1 week workshop. It can be used for a variety of uses including a small house or on the beach for storage of beach furniture and also as a lifeguard station. It could be used in resorts without the shipping container at the bottom as well.

The structure includes a shipping container at the ground, which will sit on a concrete foundation and first floor will be a nice shady space for relaxing. The structure uses approximately 100 bamboo poles of 6-9m length.



Building bamboo frame structure around the shipping container (Photo: JS)



External view of the bamboo container home (Photo: JS)



External view of the bamboo container home (Photo: JS)

## GLAMPING TENT

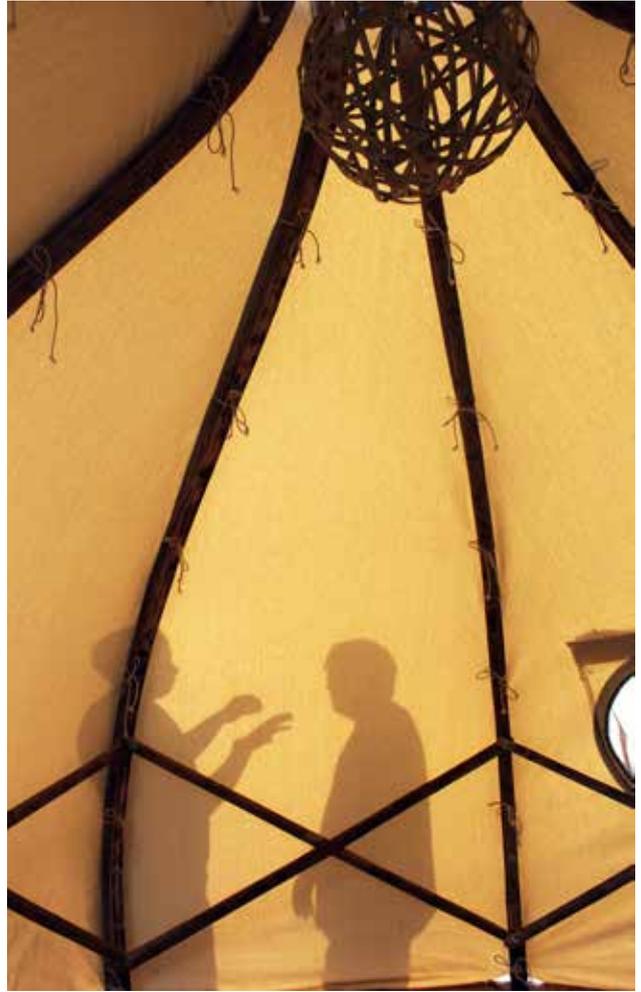
Giant Grass built this glamping (glamorous camping) tent for a client in Melbourne, Australia. The tent is made from hand laminated bamboo strips and a waterproof cotton canvas. The tent is designed as an organic shape that is in harmony with nature. It includes operable flaps allowing a connection between inside and outside.

The bamboo frame is made of laminated bamboo strips that are heat bent and bolted together on a jig. Once bolted each frame becomes rigid and strong without needing any glue. The decking is made from recycled timber pallet, which is generally waste after shipping and is easy to find for free.

A high quality tent like this can be a great addition for tourism in Vanuatu and promote alternative accommodation and eco-tourism. The large bamboo in Vanuatu, *Dendrocalamus Giantus* will be suitable to make bamboo strips that can be used to make structures like this.



Glamping tent from bamboo and canvas (Photo: MV)



Internal view of the glamping tent Photo: MV)



Night view of glamping tent (Photo: MV)

## GAZEBO/PAVILLION

A bamboo gazebo is a very simple structure that can be used for various things including a place for gathering. It can also be used for car ports and provide shelter in various conditions.

This simple design is a good starting point to train craftsmen in the basics of building with bamboo as it is small in scale and can be built using simple construction techniques.



A simple four post gazebo (Photo: JS)



Construction of a four post gazebo (Photo: JS)



Inside view of a gazebo (Photo: JS)



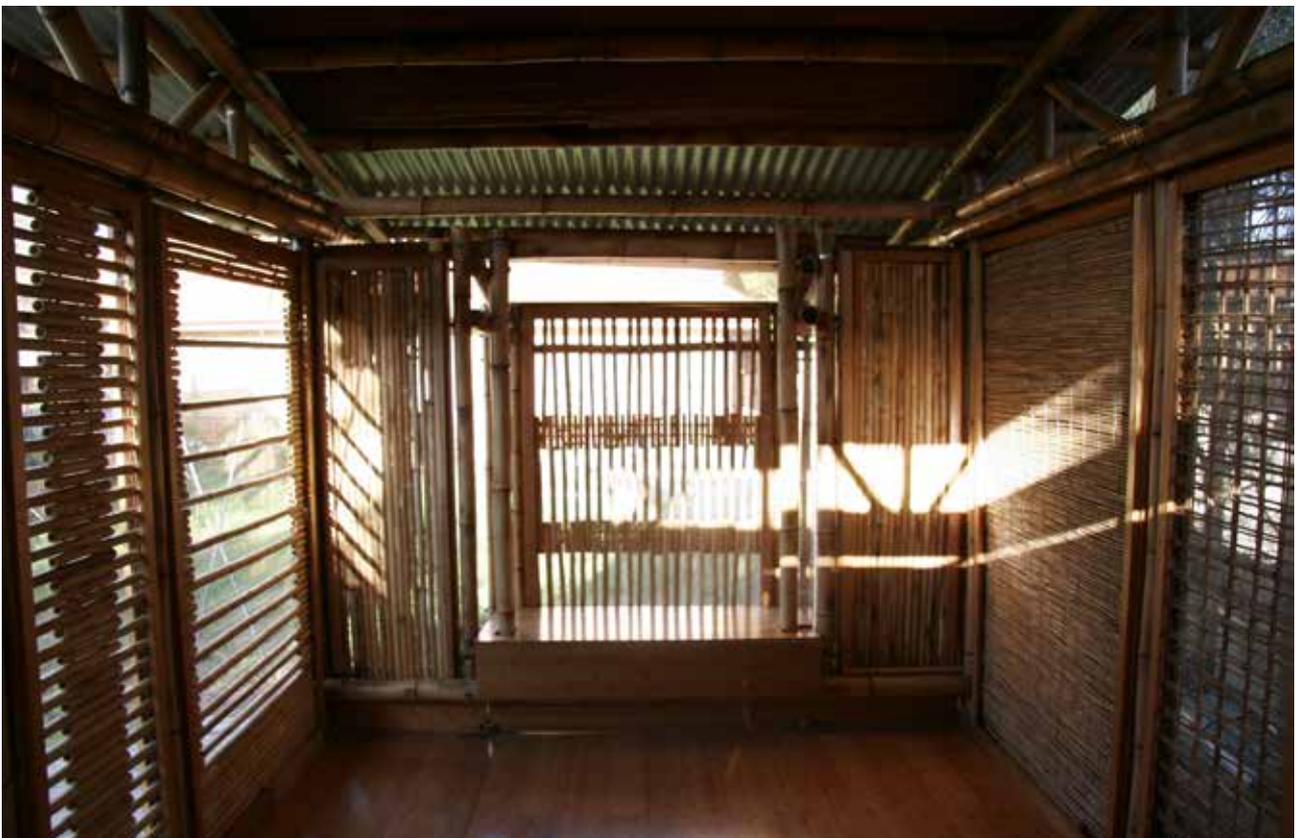
A modern pavilion with double level roof can also function as a car port (Photo: JS)



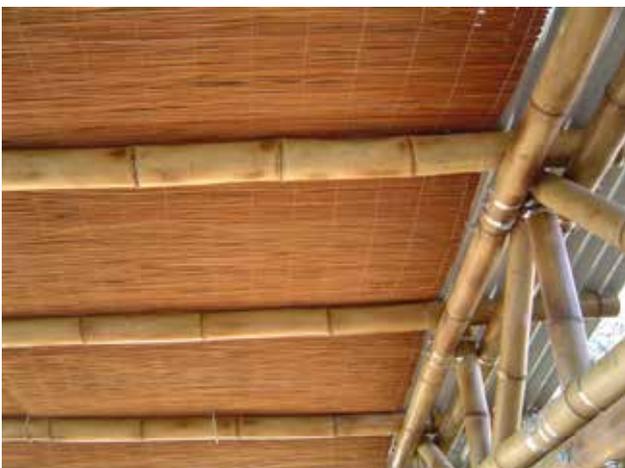
A simple four post carport with a flattened bamboo roof detail (Photo: JS)

## ECO CABIN

This building was built by Giant Grass as part of a bamboo workshop in Sydney Australia as part of the Bamboo Loveshack Project with UNSW. It is perfect for a eco-cabin and would be suitable for boutique resorts that promote eco-tourism in Vanuatu. The design uses various type of bamboo and highlight bamboo construction techniques using different screen designs and a simple curved roof.



Exterior and interior view of the cabin (Photo: MV)



Oblique view of the cabin with construction details (Photo: MV)

## BEACH KIOSK

A small prefabricated and modular shop with colourful panels that can be used on the beach to sell food and other items.

The shutters provide the ability to lock the shop when not in use and when open they provide shelter to the customers.



Exterior view of the shop with shutters open (Photo: JS)



Various pre-fabricated wall panels (Photo: JS)

## 4.3 BAMBOO FURNITURE AND PRODUCTS

Bamboo is a great material to use for furniture and other household products. It has been widely used for furniture around the world and can provide a huge opportunity for growth in Vanuatu.

This section identifies some design options that could be built by local craftsmen in Vanuatu.

### BAMBOO SEATING

Bamboo is great for making furniture including chairs, benches and seats. Availability of a variety of different species Vanuatu will allow to make various types of designs. Bamboo furniture is highly valued in the eco-tourism industry and can provide a local market to the craftsmen of Vanuatu.

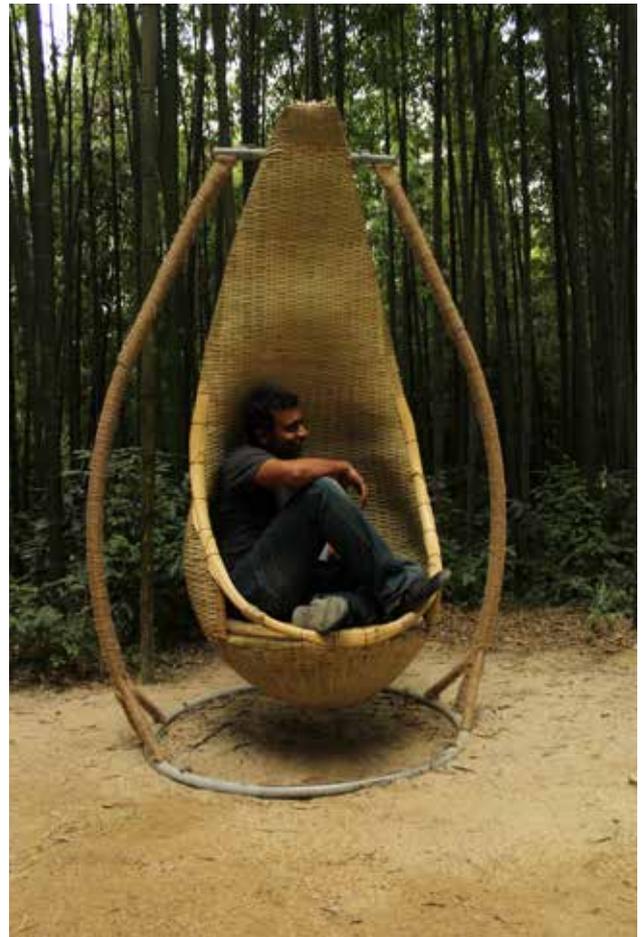
This section showcases a selection of bamboo chairs, benches and swings that can be made in Vanuatu. It would also be valuable to develop unique furniture designs that are culturally specific to Vanuatu and also can be made from locally available bamboo and local skills.



Bamboo Lounge chair with backrest made from bamboo strips (Photo: MV)



Bamboo hammock (Photo: MV)



Bamboo hanging chair (Photo: MV)



Various designs of bamboo lounge chair (Photo: MV)



Bamboo benches made from cylindrical bamboo poles (Photo: MV)



Woven bamboo bench made from bamboo strips (Photo: MV)



Traditional bamboo stool (Photo: MV)



Stool made from bamboo strips (Photo: MV)

## BAMBOO LAMPS

Bamboo lamps are one of the most popular products and are widely used in eco-tourism and resorts. When it comes to making lamps from bamboo, the possibilities are immense. The wide variety of bamboos available in Vanuatu makes it easy to make different types of lamps using minimal resources and tools. Bamboo lamps are considered a high value product and can contribute significantly towards the economy.



A round bamboo lamp made from randomly woven bamboo strips (Photo: MV)



Lamp made from thin slices of bamboo nodes (Photo: MV)



Lamp made from small balls woven from thin bamboo strips (Photo: MV)



Pendant lamp made by splitting a single piece of bamboo (Photo: MV)



Floor lamp made from split woven bamboo (Photo: MV)



Various types of woven bamboo lamps made from fine bamboo strips (Photo: MV)



# 5. DEVELOPMENT OPPORTUNITIES

# 5. DEVELOPMENT OPPORTUNITIES

A development of a regional small-scale industry, based on their own natural resources, their own skills, and their own cultural heritage is the way to go. National and international support is needed to create Vanuatu's own national bamboo industry. The national government, actually running this project through the Ministry of Industry should join forces within its Ministry of Forests and conduct a countrywide resource survey with special focus on the different species available.

Bamboo industry has a huge potential in Vanuatu based on the available resources, climate and existing skill and interest in working with bamboo. A systematic approach in terms of training and skill development is required to develop a sustainable industry. This would need to be supported by appropriate facilities and infrastructure to make sure the industry can attract quality people and sustain livelihoods.

This section identifies three key development opportunity areas as a priority to further the initiative of developing a bamboo industry in Vanuatu.

## 5.1 BAMBOO TREATMENT AND MANUFACTURING

High quality bamboo is essential to developing any sustainable bamboo industry. A treatment facility that can provide high quality bamboo poles should be developed on the island to ensure a constant supply of treated bamboo poles.

An appropriate bamboo treatment facility should be designed and developed at a designated location on the island. The best approach to identify a site for the facility that is central and develop a design for the facility by a bamboo expert. Local villagers should be involved in the development and construction of the facility to ensure that they have the relevant skills to maintain and manage the facility in the future. It is possible to combine the construction of such a facility with a bamboo construction workshop so that the craftsmen not only learn how to treat bamboo poles but also build the structures out of bamboo thereby developing bamboo construction skills.



Large on-ground tank for bamboo treatment  
(Photo: JS)



Bamboo structure designed to store treated bamboo poles (Photo: JS)



## Workshop 1 - Bamboo treatment and construction workshop

Organise a 3-4 week bamboo treatment and construction workshop, which results in the construction of a bamboo treatment facility and also training around treatment of bamboo poles and construction techniques.

## 5.2 LAMINATED BAMBOO STRIPS

The availability of bamboos like *Dendrocalamus giganteus* makes the use of bamboo strips a great option for Vanuatu. Designing with bamboo strips can expand the possibility of using bamboo in various innovative ways that is not possible with round bamboo poles. It is possible to laminate bamboo strips to make structures like the Glamping Tent as discussed before or even make furniture, flooring and other products.

Building with bamboo strips requires a different set of tools and skill sets to building with round bamboo poles. It is highly recommended that a detailed training session focused on making and using bamboo strips be carried out to develop this type of bamboo industry.



Heat bent bamboo strips on a jig (Photo: MV)



## Workshop 2 – Making and using bamboo strips

Organise a 2 week workshop focused on manufacture of bamboo strips along with training around building structures using bamboo strips like the Glamping tent.

## 5.3 BAMBOO FURNITURE AND HOUSEHOLD ITEMS

Bamboo furniture and other household items are highly valued in the tourism industry and become a basis for a bamboo industry. It is important to develop a unique identity for a local industry so that it can become a valued item globally.

It is recommended that a Skill and Design Development workshop we organised focused on developing new and unique designs that reflect Vanuatu's culture and identity. Local craftsmen can be taught how to build these items, which can provide livelihood to the people.



Local craftsmen making new designs as part of a Skill and Design Development Workshop  
(Photo: MV)



### **Workshop 3 – Skill and Design Development Workshop**

Organise a 2 week workshop to develop new designs that are suitable for the available bamboo and reflect local culture and tradition. Craftsmen will learn how to make these designs and also sell to local and international markets.





