Humanitarian bamboo

Draft 2, 2009

HUMANITARIAN BAMBOO
A manual on the humanitarian use of bamboo in Indonesia

FOREWORD

These guidelines have been developed as a NO LOGO project, with the generous support of Oxfam Great Britain's PRIME project in Jogjakarta, Indonesia. The project has been managed by by Dave Hodgkin from Benchmark Consulting. Contributions and assistance have been received from numerous bamboo and disaster response experts, both in Indonesia and India, and Shelter Cluster participants globally.

The first draft of these guidelines provided a general layout of the document along with some brief commentary about each potential section. This second draft provides the first overall document ready for technical verification from key advisors as well as for use in the field. The third draft will include any further recommendations and will be made available in both Indonesian and English language versions.

The second draft is also available on the Humanitarian Bamboo website at www.humanitarianbamboo.org

Any feedback or input into the further development of this document is much appreciated. All comments should be sent to:

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- Ruth, Kim, Thor, Ben, Ale, Bakti and many others.

The above list is far from complete as many individuals and organisations, both local and international have provided valuable input into the development of this document. The author apologises for any omissions.

SECTION DESCRIPTION

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1. Introduction to the manual
2. Introduction to bamboo
3. Deciding to use bamboo

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1. Crop management and harvesting
2. Treatment
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GLOSSARY OF TERMS

TERM	MEANING
Beams	Major horizontal structural elements of a building.
Bracing	Elements incorporated into a building to stop the building from racking (rocking) under changing loads.
Clump	A group of culms forming one individual bamboo plant.
Clumping species	One of two major groupings of bamboo, technically known as leptomorphs or monopodial species, in which new rhizomes form from the base of existing culms, resulting in a close knit stand. The fibres of clumping species are generally more intertwined than those of running species. The vast majority of all equatorial bamboo are clumping varieties.
Columns	Major vertical structural elements of a building.
Culm	The common term for one individual stick of bamboo within a clump.
Eaves	The element of a roof that hang over the external walls.
Fishplate	A bridging element applied to the side of one or two building elements to provide reinforcing and strengthening across a weak point in construction
Inter-nodal space	The hollow section of tube between any two nodes in a bamboo culm.
Joists	Horizontal structural elements that flooring or roofing is attached to.
Lintels	Horizontal structural elements above an opening (e.g. a doorway or window), designed to ensure transfer of the load to either side of the opening.
Node	The solid section that regularly breaks up the hollow tubular section of a culm.
Nogs	Small spacing elements placed between larger construction elements(such as studs or rafters) to prevent them from buckling or twisting.
Peg or dowel	Small construction elements, commonly made of timber or bamboo, driven through holes in adjoining pieces of timber or bamboo to pin the two pieces together.
Racking	Swaying or warping of a structure when horizontal loads are applied.
Rafter	Structural roofing pieces that extend from the ridge of the roof down to the external walls, or beyond the external walls to create eaves.
Rhizome	The below-ground shoot that forms the starting point for the development of a new culm.
Rhizome bud	The newly formed rhizome as it branches away from the main clump.
Ridge	The horizontal construction element that forms the highest point of two or more intersecting roof planes.
Running species	One of two major groupings of bamboo, technically known as sympodial or pachymorph bamboos. Rhizomes form from underground runners up to 30 metres from the last culm, allowing the bamboo to spread over an ever increasing area. The fibres of running varieties are generally much straighter than those of clumping species. These species mainly occur further from the equator in colder northern climates such as China.
Shoot	The early section of a newly emerging culm as it first appears above the ground. This section of the bamboo is highly nutritious and edible for both humans and livestock.
Under purlin	Horizontal structural elements that support rafters or joists.
Warpage	Twisting and bending of bamboo or timber over time, commonly caused by exposure to adverse conditions, such as heavy loads or bright sunlight.

Section A

Introduction

Key Points

- This section of the guidelines introduce the key issues involved with using bamboo in post-disaster humanitarian shelter programming, and aims to bring together humanitarian workers' understanding of emergency response and bamboo experts' technical knowledge of bamboo construction.

- Bamboo is an ideal resource for use in humanitarian shelter programming due to its high strength, low cost, rapid growth and high availability across many disaster-prone regions.

- When deciding whether to use bamboo, a number of factors should be considered including availability of skills and resources, as well as the acceptability of bamboo to the community.

A.1 INTRODUCTION TO THE MANUAL

A.1.1. OUTLINE AND STRUCTURE

This manual comprises four sections:

- Section A introduces bamboo and bamboo construction, including important considerations when deciding whether to use bamboo in humanitarian programming.
- Section B outlines issues related to sourcing bamboo, including crop management, harvesting, treatment and procurement.
- Section C looks at building with bamboo, including design, construction and maintenance considerations.
- Section D provides a list of additional resources.

A.1.2 RATIONALE

In response to the 2006 Jogjakarta earthquake, over 70,000 24m^2 bamboo transitional shelters, with an average cost of $US100-200, were erected over 9 months. The construction of these shelters was one of the largest and most rapid post-disaster shelter responses in recent history, at relatively low unit cost and with minimal environmental impact.

From the Jogjakarta earthquake response, it became clear to many agencies that although bamboo is a cost-effective, strong, cheap, rapidly constructed and readily available material, many humanitarian workers lack experience in using bamboo and lack clear guidance on best practice in bamboo construction. Therefore, these guidelines have been produced to help humanitarian workers make better informed decisions about when and how to use bamboo in post-disaster shelter responses. The guidelines aim to provide an open source, "no logo" bridge between the technical knowledge of bamboo experts and the disaster response experience of humanitarian workers. The guidelines aim to provide a general introduction to best practice, while providing specific examples from the Indonesian context.

A.1.3 PROCESS

These guidelines are being developed in conjunction with the website www.humanitarianbamboo.org to provide initial guidance to workers who are considering using bamboo in post-disaster response. The guidelines are in no way comprehensive; practitioners should seek the advice of technical experts and local tradespeople to provide more specific advice on their individual programs.

The production of these guidelines has been broken into a number of steps:

Consultative workshops were conducted in Jogjakarta, Indonesia and Pune, India to provide advice on content.

Indonesia-specific guidelines were produced, with the first draft written in English and translated into

Indonesian.

A website is being developed as a repository of information about bamboo programming.

A more international set of guidelines maybe developed, depending on acceptance and relevance of these initial guidelines, and the website could also be expanded to provide a larger collection of international information.

A.1.4 TARGET AUDIENCE

This manual is primarily for humanitarian practitioners in the field, providing them with guidance on best practice in bamboo use and construction. Other audiences may include:

- Members of disaster-affected communities who are looking for guidance on what to expect from humanitarian workers, or for guidance on their own bamboo projects.
- Donors who are looking for guidance on best practice in the sector, or who would like assistance in assessing funding proposals for projects using bamboo.

A.1.5 DISCLAIMER

It is almost impossible to produce a set of guidelines short enough to be read in the limited time available to emergency workers but detailed enough to provide clear technical advice on all aspects of bamboo use. Therefore this manual introduces the reader to the key issues of bamboo use in post-disaster shelter programs, and provides a website with additional references and sources for those requiring further information.

Post-disaster shelter programs aim to assist families along the path from post-disaster homelessness to adequate shelter security. The design of such programs must therefore include extensive input from the local community. Bamboo construction methodology is intricately linked to local culture and varies greatly from place to place — quality programming will integrate the principles from these guidelines with local wisdom.

The information presented in this manual is for general guidance only, as with any humanitarian program all advice should be checked against local knowledge and technical expertise before applying it to a specific situation.

A.2 INTRODUCTION TO BAMBOO

A.2.1 BAMBOO THE PLANT

Bamboo is one of the most useful plants known to humanity. All parts of the plant are used: shoots provide nutritious food, leaves provide fodder and stalks provide construction materials. Bamboo is used in more than a thousand ways, including post and beam construction, formwork, food, fodder, musical instruments, piping, walling, flooring, mats, baskets, roofing, cooking utensils, medicine and charcoal.

Bamboo is a highly versatile, strong and renewable resource, and it is used throughout the world. In Indonesia, for example, bamboo is an intrinsic part of daily life: homes are built from bamboo, floors and walls are covered with bamboo, bamboo baskets and pots adorn houses and countless bamboo bridges cross small streams and rivers.

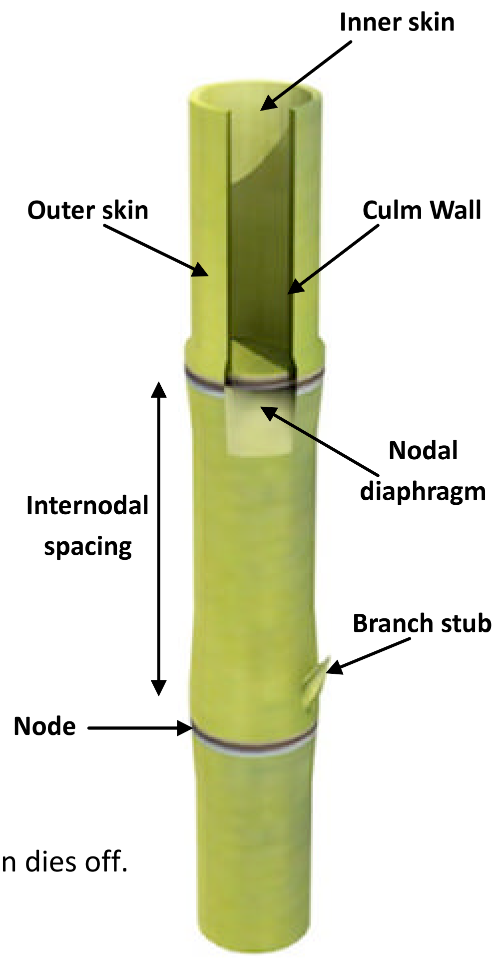
You can watch it grow!

The tallest bamboo can grow at up to 1–2m per day, reaching heights of over 35m in one growing season. That's 15–20cm over lunch.

More than 1000 species of bamboo have been identified, and more than 100 species have been classified as 'woody species' suitable for construction. In Indonesia alone there are more than 140 known species, of which at least 16 are commonly used in construction.

GROWTH PATTERN OF BAMBOO

Bamboo is technically a form of grass, growing in clumps or forests of large tubular sections known as culms. Bamboo can be broadly divided into two groups: running and clumping. Clumping species sprout their new shoots close to the base of existing culms whilst running varieties may send out shoots as far as 30m from an existing culm, potentially as far as the culms are tall. Most tropical species such as those found in Indonesia are of the clumping variety, whilst running varieties are largely confined to colder northern regions such as China.



Bamboo differs greatly from timber both in growth pattern and structure. Unlike timber, individual bamboo culms grow to their full height and girth in a single growing season, whilst the overall clump reaches peak production at around 7 years and can maintain regular cropping of around 20-25% throughout its productive lifecycle, until the plant finally flowers and then dies off.

LIFECYCLE

The lifecycle of the bamboo plant commences like any other plant, sprouting forth from a seed and sending up its first shoot to form a new culm, which sprouts leaves to commence photosynthesis. The first culms in a new clump are limited in size by the photosynthetic capacity of the new clump resulting in smaller culms until sufficient culms exist for new culms to reach full height.

Full size in 3 months

Unlike timber which may take tens or hundreds of years to reach full height, a culm of bamboo reaches its pinnacle in one season, only toughening up over the next years.

As the wet season approaches, new rhizomes buds form underground. Then as rains commence, the rhizomes form new shoots that sprout into that seasons' culms, reaching their full height and width over the first rainy season of only 3- 4 months. During the first season, culms are so busy shooting up that it is only over the next year that they then commence to send out branches and begin to photosynthesize. In their first year, bamboo culms depend entirely on the health of the clump in the first year to reach their full height.

BAMBOO LIFE CYCLE FROM SHOOT TO CULM

Over the next 2-3 years culms dry out and toughen up, reaching their full strength and maturity at around 4-5 years. By 6-7 years fungal attack, rot and age begin to set in and the culms finally succumb falling to the ground to rot and provide feed and protection for newly forming shoots.

The life cycle of individual culms means that a new clump reaches full maturity and maximum production capacity at around 7-10 years. The plant then continues on until eventually flowering and then dying off. The full life cycle of a culm varies greatly from species to species. Small ornamental species may flower and die off annually whilst the larger woody species used in construction may have a life cycle from 60-160 years.

Bamboo mass flowering

In many larger bamboos, flowering occurs en masse across a species, in cycles that may be once in 100yrs+, Such mass flowering events may cause great change to ecosystems wreaking havoc in communities that depend on the bamboo, or who may be heavily affected by ensuing plagues of seed-eating pests and their predators such as rats and then snakes.

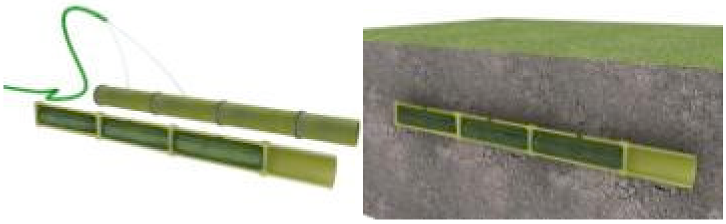
Many larger woody species die off in sudden mass flowering events that may cause great havoc to dependent communities who can be adversely affected by ensuing plagues of animals such as rodents feeding off the mass seeds and then by further plagues of predators feeding on them.

CULTIVATION

Bamboo may be grown either directly from seed, through cuttings, or by divisions of clumps. As many woody species have long periods between flowerings, with often low rates of germination from seed (below 1%), this is the least common method of cultivation. Smaller plant varieties are easily handled and therefore commonly cultivated through clump separation, whilst larger varieties are generally propagated through cuttings.

COMMON METHODS OF BAMBOO PROPAGATION: CLUMP SEPARATION AND CUTTINGS

A common commercial method of propagating woody bamboo species involves horizontally burying cuttings that are 3-4 nodes in length around six inches below ground prior to onset of the rainy season. Holes are cut midway between nodes, with each segment then filled with water prior to burial. New shoots then form from the nodal joints.



BAMBOO SECTIONS FILLED WITH WATER THEN BURIED FOR SPROUTING.

Concern about the impact of mass bamboo construction projects on local community stocks may lead agencies to consider community replanting programs. Bamboo cultivation is outside the primary focus of this document but for more information please refer to the recently published book by the Environmental Bamboo Foundation on the harvesting and management of bamboo.

DISTRIBUTION

Bamboo growth is largely confined to high rainfall, tropical regions, though it can grow in colder temperate or sub-temperate zones. Bamboo of differing species, quality and quantity occurs across most of Indonesia.

For further detail on distribution in Indonesia, see *Section D.3 Distribution maps of bamboo in Indonesia.*

A.2.2 INTRODUCTION TO BAMBOO IN HUMANITARIAN CONSTRUCTION

Bamboo's combination of high tensile strength and lightness make it an ideal material for rapid construction of emergency or temporary housing. When well-built, the high tensile strength and flexibility of bamboo makes bamboo shelters highly resistant to damage by strong wind, floods and earthquakes. These factors, combined with bamboo's low cost and ease of availability in most of the disaster-prone tropical regions make bamboo an ideal material for use in many humanitarian projects.

Housing the world

An estimated 1 billion people across the globe currently live in homes made from bamboo.

Bamboo is used for construction throughout the world with major research bases in China, India, Hawaii, Indonesia, Brazil, as well as in Europe and America. More than 200 species of woody bamboo are used in constructing such diverse objects as furniture, houses, temples, water tanks, high rise buildings, scaffolding, bicycles and cutlery. Treated and well-maintained bamboo structures have as long a life expectancy as their timber equivalent, with the world's oldest bamboo structures surviving thousands of years.

Bamboo may be used for almost all aspects of construction, from roofing to flooring, wall framing to wall and floor cladding; even piping of water is possible in bamboo.

Building with bamboo does however pose challenges to many aid workers who may have little experience of this unique material. Although similar in many ways to building with timber, utilizing the same tools and general framing techniques, bamboo design and construction does have its own particular requirements. Although as strong as mild steel in vertical tension or compression, bamboo's hollow tubular section is easily crushed between nodes; hence nodal placement becomes key to the success of any bamboo structure. Bamboo culms are also more prone to splitting when nailed or screwed, hence a range of other fastening methods need to be considered.

It is critical to understand that the durability of bamboo structures is dependent on a number of key factors including the quality and species of bamboo used, the weather resistance of the design, and the strength and stability of the structural joints. This document provides an introduction to these issues, but local knowledge and good technical advice should be sought on a case per case basis.

A.3 TO USE OR NOT TO USE BAMBOO

The appropriateness of bamboo for a given humanitarian program needs to be carefully thought out. Factors that must be considered are diverse and complex.

CONSTRUCTION SKILLS
DOES THE COMMUNITY HAVE DEMONSTRATED KNOWLEDGE OF BAMBOO CONSTRUCTION?

DURABILITY
WILL TEMPORARY BAMBOO STRUCTRES BE DURABLE ENOUGH UNTILL PERMANENT SOLUTIONS ARRIVE?

NEED TO INTERVENE
NEED FOR ASSISTANCE = (DAMAGE LEVELS X LIKELY HEALTH IMPACTS) MINUS COMMUNITY + GOVT CAPACITY TO ASSIST

BAMBOO SUPPLY
ARE THERE SUFFICIENT BAMBOO RESOURCES IN THE AREA?
ARE THESE RESOURCES ADEQUATELY MANAGED?

TRAINING
WILL TECHNICAL TRAINING BE REQUIRED? IS IT FEASIBLE AND APPROPRIATE? CAN WE FIND LOCAL TRAINERS OR WILL WE NEED TO BRING THEM IN FROM ELSEWHERE?

?

MOST APPROPRIATE RESOURCE
IS BAMBOO THE MOST AVAILABLE AND APPROPRIATE RESOURCE? HAVE COCONUT WOOD, CONCRETE, TIMBER OR OTHER RESOURCES BEEN CONSIDERED?

ACCEPTABILITY
THE LOCAL GOVERNMENT, DONORS AND OR THE AFFECTED COMMUNITY MAY PERCIEVE BAMBOO AS A LOW STANDARD MATERIAL. HAVE THEY BEEN CONSULTED? CAN WE SUPPLY INFORMATION ON QUAILTY BAMBOO CONSTRUTION?

TREATMENT
WILL THE BAMBOO NEED TO BE TREATED PRIOR TO USE? IS TREATED BAMBOO AVAILABLE, OR WILL BUILDING A TREATMENT FACILITY BE REQUIRED?

PROCUREMENT
WHO WILL UNDERTAKE PROCUREMENT? THE COMMUNITY, OR THE AGENCY?
HOW WILL BULK PROCUREMENT IMPACT IN THE AFFECTED COMMUNITY AND ITS RESOURCES?
DOES PROCUREMENT FURTHER AFIELD NEED TO BE CONSIDERED?

AID EQUITY
WHAT ARE OTHER SHELTER ACTORS PLANNING?
CAN THIS PROJECT SUPPLY AN EQUIVALENT-VALUE SOLUTION?

Section B

Sourcing

1. Material sourcing and specifying
2. Crop management and sustainable harvesting
3. Treatment
4. Logistics and handling

Key Points

The importance of bamboo as a local community resource makes it essential that humanitarian workers consider the effect of large-scale procurement on regional bamboo stocks, and set in place systems that address potential negative impacts.

To treat or not to treat bamboo is an overarching decision that will affect all levels of programming and needs to be considered early on in program design and procurement.

Bamboo is commonly a community resource; hence the voice of the community is important at all stages of procurement of bamboo and bamboo products.

B.1 MATERIAL SOURCING AND SPECIFYING

Sourcing bamboo in sufficient volume and quality proved to be a major challenge for many agencies during the 2006 Jogjakarta earthquake response, with some agencies consuming over 10,000 culms a day at their peak. It is critical when designing large scale programs to carefully consider the impact of such large scale purchasing on both the available resource and the local market.

Relative merits of procurement options

	Community	Local or regional	National
Pros	• Funds injected at the lowest level into a community can produce up to 8 times the economic benefit for the affected population. • Quality control enforced by the home owner. • Increased "ownership" of the program. • Works well with rural communities who have a good understanding of bamboo selection and construction.	• Easily centrally controlled. • Inspection of suppliers, sources, business premises and storage facilities can be easily conducted. • Puts money into local business helping kick-start the economy.	• Potentially larger, more professional suppliers. • Potentially spreads the environmental impact over a larger area. • Reduces the impact on local markets.
Cons	• Requires higher levels of financial control. • Requires community training for quality control. • Urban communities may have little or no experience in procuring and constructing in bamboo.	• High potential for short term impact on the local price of bamboo, potentially pricing self-recovery groups out of the market. • Potential for high level short-term and even long term impact on local bamboo crops.	• More difficult to inspect offices, storage and transport facilities. • Harder to regulate harvesting practices, hence potential for increased environmental impact, albeit further afield. • Requires stricter tendering processes and controls, hence often slower to instigate.

NOTE: The decision to use treated or untreated bamboo must be fully integrated into procurement plans as many treatment systems require bamboo to be treated within days of harvest, whilst the life expectancy of non-treated bamboo is very dependent on how and when it was procured and handled. See *Section B.3 Treatment*.

B.1.1 SELECTION AND GRADING

The quality of any given construction is only as good as the material it is made from. A large range of factors can affect the quality of bamboo, including when it is harvested, its age etc. The following list provides some guidance on bamboo selection. This guidance can never replace the wealth of local knowledge regarding local markets and bamboo species and quality.

AGE

Most species of bamboo achieve their peak strength between 3 and 6years of growth. Hence it is critical to good programming that the age of culms is checked at the time of procurement. Furthermore, the harvesting of immature bamboo may adversely affect crop productivity for many years to come. See *Section A.2 Crop management and sustainable harvesting.*

Exact indicators of age vary greatly from species to species, making it is essential to work with local bamboo experts to develop a set of age indicators that can be agreed upon as acceptable by both the suppliers and the affected community. However some common indicators include:

- During the first years of growth, the juvenile leaves that form as each branch forms are still visibly attached to the main stalk of bamboo. As bamboo ages these fall away.
- As bamboo ages it loses its fresh green colour, slowly darkening to pale brown.
- As bamboo ages the walls begin to dry out and harden, causing the internodal walls to shrink, showing wrinkles.
- Perhaps the surest test of age is the sound or tone the bamboo produces when struck. Bamboo that is too young or too old has a much flatter tone than the tone produced by the firmer correctly aged bamboo. A small amount of practice will clarify the correct tone for any given species.

Checking the age of bamboo		
Too young	**Correct age**	**Too old**
• First-year growth will have no signs at all of vestibule branches having formed. • The juvenile sheathes that form to protect newly emerging branches may still visible on the culm. • Dull tone and damp cold feel. • When sliced, the bamboo is wet, sweet and soft.	• Some collapse in width between nodes and some minor wrinkling of skin surface. • Firm and tight tone(although hard to describe, this often the simplest and most effective test of suitability for construction).	• Juvenile cracks and splits forming across nodes. • High levels of collapse in width between nodes or highly wrinkled surfaces. • High levels of visible fungal attack. • Dull tone when tapped. • Easily snapped or crushed. • Dull brown in colour even though freshly cut.

SIZE

When specifying bamboo sizes in large quantities, it is important to consider the impact that the often large-scale bulk procurement involved in humanitarian work can have on local markets. Diversifying the sizes and species being procured can greatly reduce the impact on any one resource.

Ideally, bamboo houses are built using 3 or 4 different sizes and or species of bamboo. Commonly, larger sized elements (6" and above) are used for posts, while structural beams and trusses may use 3" or 4" material. Rafters are commonly 2-3" whilst batons may only require 1-2" material or split bamboos. Flooring or cladding material may have yet different requirements .

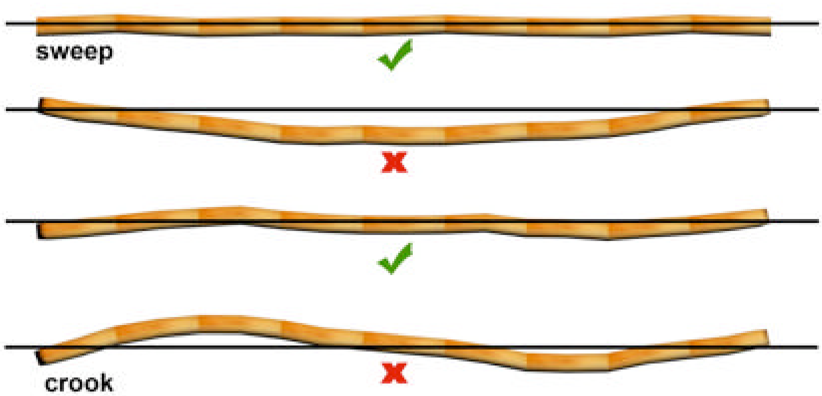
Bamboo is commonly sold in a limited number of pre-setwidths and lengths. Lengths may very from area to area depending on truck sizes, whilst common widths are more often based on species availability and market demand. In Indonesia, bamboo is commonly sold in lengths of 6m with diameters of 5, 7.5, 10 and 15cm.

Sketch or photo
of
simple measuring tool

When setting in place procurement procedures to determine minimum and maximum sizes of bamboo, a simple tool can be made from a flat plan with two holes cut into it. If the small end of the bamboo can be slipped into the small hole the bamboo is too small and if the large end of cannot be slipped into the large whole then it is too large. A tolerance of 5-10% across a truck load may allow for some variation in what is needed on site, whilst reducing the burden on the supplier.

STRAIGHTNESS

For predictability of strength loads and replicability of design, culms should be of a reasonable level of straightness. Acceptable levels of "sweep" and "crook" may be measured using a stringline stretched from the tip to the butt of the culm. No part of the culm should fall outside of the line of the string.

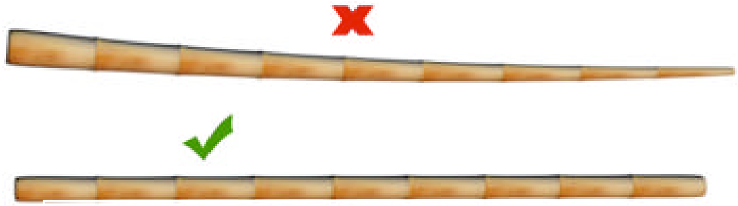


Note: Mildly bent culms may be suitable for use as shorter members such as nogs and bracing, whilst keeping the straightest sections for longer applications such as rafters and poles.

TAPER

For ease of construction and consistency of strength, culms should be selected with a minimal level of taper along the length. A maximum taper of 10mm per 3m of length is commonly considered acceptable.

Overly tapered culms are one common symptom of over-cropping of a clump prior to full maturity.



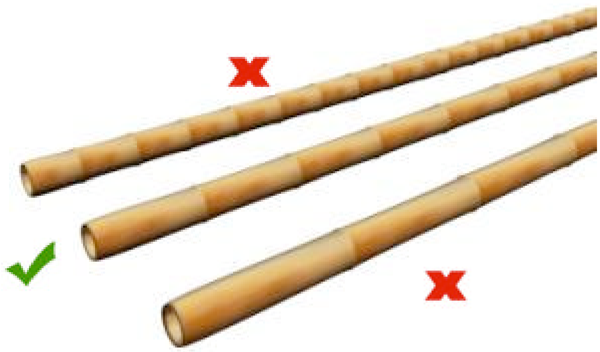
ACCEPTABLE TAPER 10MM PER 3M

NODES

Bamboo is straight between nodes, altering direction slightly at the node. Hence bamboo with tight nodal spacing may make for irregular-shaped culms that are more difficult to build with. Wider nodal spacing (30cm-60cm) makes for straighter bamboo and therefore easier construction. Overly wide spacing limits the horizontal strength of the culm.

The length of nodal spacing is generally a feature of the particular species, though narrow spacing may be caused by viral attack and stress when growing.

Good planning and culm selection on site can ensure best nodal placement for important structural joints.



IDEAL BAMBOO FOR CONSTRUCTION HAS NODAL SPACINGS OF BETWEEN 30 AND 60CM

SPECIES

Suitable species for use in humanitarian programming vary greatly from area to area and application to application. The vast variation in characteristics and properties between species makes accurate selection essential.

As a general guide, species most suited to main poles have thick pulpy walls whilst species for general construction use such as rafters, have thinner but denser walls. A large variety of species are used for woven sheeting and handicrafts depending on the exact needs of the product being produced.

EXAMPLES OF SPECIES DIVERSITY:THIN-WALLED BAMBOO SUITABLE FOR RAFTERS, THICK-WALLED SUITED TO POLES AND SOLID BAMBOO USED FOR HAMMER HANDLES

Local advice should always be sought in any area for the most appropriate species for a given application.

INSECT AND FUNGAL ATTACK

Bamboo should be checked regularly for signs of fungal decay or insect attack during purchasing, storage and construction. Damaged material should noted and rejected. Most such damage is due to excessive age of the culm at time of harvest or is an indication of poor storage, handling or clump management. procedures.

ADVANCED FUNGAL ATTACK ON BADLY-MANAGED BAMBOO CLUMP

PINHOLE BORER ATTACK ON AGING BAMBOO SHEETING

The most common forms of insect and fungal attack in bamboo are from the pinhole (or powder) borer beetle, fungus, wet rot and termite attack. Each of these flaws in bamboo can be easily detected using the following table of indicators.

The majority of fungal and insect attack prior to construction is preventable through a combination of improved harvesting and sap leaching to reduce how edible bamboo is, along with improved handling and storage. Post construction pest issues may also be caused by poor design allowing excess exposure to humidity and ground contact.

	INDICATORS	NOTES
POWDER BORER	• 1-3mm bore holes (exit holes) occurring sporadically over the surface of the bamboo. Exit holes usually begin at the node. • Small piles of very fine dust on the ground below the bamboo. • Entrance at nodal points and ends.	• Powder borer is perhaps the most common cause of damage in bamboo. • Harvest bamboo at times when sugar level is lowest in the sap will reduce its attractiveness to powder borers, particularly in dry seasons.
FUNGAL ATTACK	• Mould-like spores can be seen growing on the outside of the bamboo. • Bamboo develops a damp mushroom-like smell and culm walls become soft.	• Fungal attack occurs due to prolonged exposure to excessive humidity. • Rotate bamboo regularly when stored and store in well-ventilated environment.
WET ROT	• Weakening of the side wall of the bamboo commonly at or near ends.	• Rot is caused by excessive exposure to water. Keep bamboo free from ground contact, exposure to rain, and keep area well drained.
TERMITE ATTACK	• Side walls of bamboo are eaten out, leaving behind a weak honeycomb-like structure. • Coarser piles of dust may be seen on the ground below bamboo. • Once broken open, termites are often clearly visible inside the structure.	• Generally occurs over time after construction. • Most termite attack is caused by subterranean termites, who enter through direct ground contact. • Ensure there is a physical barrier between the bamboo and the ground. • Remove damaged bamboo and spot treat with poisons that worker termites can carry back to the queen.

SPLITTING

The majority of Asian clumping bamboo species as used in construction in Indonesia are prone to splitting. Although this proves a great benefit for the manufacture of handicrafts and woven sheeting, excessive splitting can greatly weaken the strength of bamboo in construction. Excessive splitting in bamboo is commonly a sign of poor handling and storage, excessive age of the culm, or overly rapid drying in the case of freshly bamboo left for too long in direct sunlight.

MINOR SPLITTING, MAJOR SPLITTING AND END SPLITTING

Excessive splitting may be an important indicator of other problems in handling, storage, seasoning and harvesting, and as such offers an opportunity for improving quality control.

- Avoid purchasing bamboo where splitting continues through the node.
- Allow excess at either end of the culm when ordering to allow for the natural tendency of end splitting in bamboo when drying.
- Hairline splits are acceptable but should be considered as a warning of potential problems such in storage and handling or excessive culm age.
- Splits in the centre of sections of bamboo may indicate poor handling and poor felling techniques.

It is important to define and stipulate an agreed level of splitting between beneficiaries and suppliers to ensure a minimum standard is achieved that the community is satisfied with. Random checks within truck loads should occur to verify this and other potential quality issues.

B.2 CROP MANAGEMENT AND SUSTAINABLE HARVESTING

Grow your own house?

Simply by managing crops better, communities can increase the yield of their bamboo by up to 30%. Within 3-5 years, families can quickly grow an extension to their shelter.

Recent research by the Environmental Bamboo Foundation in Bali has shown that good crop management practices can increase bamboo crop yields by up to 400%, whilst poor practices (as are prone to occur in the rush of construction after a major disaster)can devastate crop output for many years, or in some cases permanently.

BAMBOO PLANTS PERFORM AN IMPORTANT ROLE IN DISASTER RISK REDUCTION, REINFORCING THE RIVERBANK AND PROTECTING AGAINST FLOODS, WHILST BUFFERING STRONG WINDS AS WELL AS PROVIDING A VALUABLE RESOURCE FOR RAPID POST-DISASTER SHELTER.

For many communities, bamboo crops perform essential roles in disaster risk reduction by strengthening riverbanks, buffering strong winds without the hazard caused by trees when blown over, and shading and cooling the local environment. Training communities in crop management and the resultant increased output can provide valuable income generation at a village level, whilst also improving community level disaster preparedness.

Grow your own protection?

Training communities in good crop management can greatly improve resilience in future disasters. As well as being a valuable resource, bamboo provides an excellent buffer for floods and storms.

The 2008 Humanitarian Bamboo Consultative Forum in Jogjakarta identified good crop management as one of the most overlooked aspects of bamboo usage in the Jogjakarta earthquake response. The harvesting of more the 20 million culms of bamboo for temporary housing seriously depleted local bamboo stocks. The forum recommended that all future bamboo-based humanitarian programs should include measures to ensure sustainable harvesting and replanting as part of their program design and procurement guidelines.

Protecting communities

Over 90% of homelessness through natural disasters is caused by wind and flood. Bamboo plays an important role in a community's resilience to these events.

B.2.1 HARVESTING

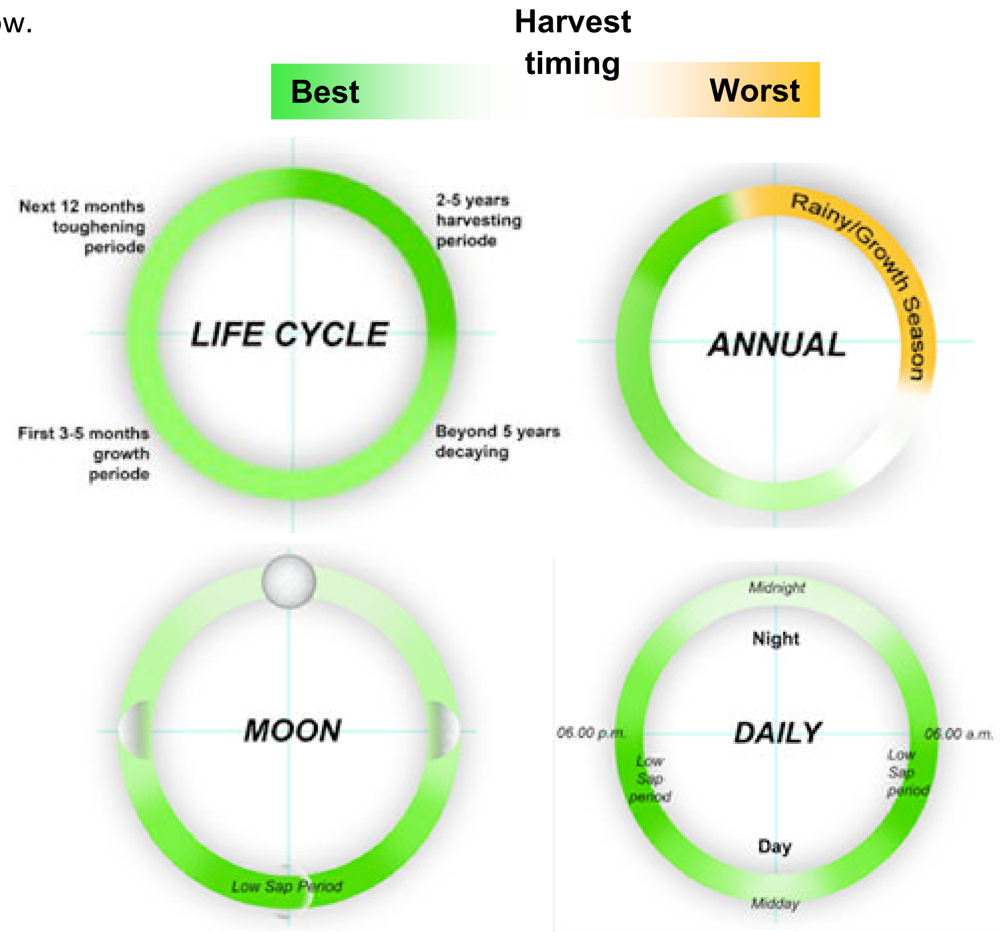
Harvesting is often the only time that communities engage with their bamboo stocks, hence providing the greatest opportunity for crop management. Although many practitioners agree that in an emergency, bamboo crops can be harvested at any time of year, it is clear that harvesting at the correct time of year and in the correct manner will greatly improve both bamboo quality and crop production, and may increase bamboo's usable life span by up to tenfold.

WHEN TO HARVEST

***In an emergency situation bamboo can be harvested at any time or stage of its life cycle*.**

However, the susceptibility of bamboo to pest infiltration is highly influenced by sap sugar levels at the time of harvest and there are preferable times for harvest, within the life cycle of the bamboo, the annual cycle of growth, the time of the month as well as the time of the day. For example, harvesting during the rainy growth season should be avoided as it will damage newly emerging shoots, reducing overall crop productivity. The guidelines below show how to increase the life expectancy of both the structure and the crop.

1) **LIFE CYCLE:** Harvest culms no younger than 3 years old and no older than 5 years old.
2) **ANNUAL CYCLE:** Harvest well outside the growth phase during the rainy season.
3) **MONTHLY CYCLE:** Consult local knowledge about the best time to harvest by moon cycle.
4) **DAILY CYCLE:** Harvest preferably at dawn when visibility is sufficient but sap levels are still low.



HOW TO HARVEST

Best practice in bamboo harvesting includes:

- To ensure adequate foliage to feed the developing clump, ideally no more than 33% of a clump should be harvested at any time
- Harvest culms at 3-5 years old (there is some variation between species).
- Cut culms immediately above the second node above the ground to reduce potential fungal attack.
- Ensure cuts are as neat as possible and clean up waste bamboo to reduce pest infestation.
- Prune the clump to allowing more light in and encourage new shoot growth. Clear out culms that are
  - too old and have begin to decay.
  - diseased.
  - broken or overly bent.
- Bamboo cells begin to collapse and close within 2-3 days of harvest, after which time they are no longer capable of transporting water. Treatment systems that make use of the plant's vascular system must be undertaken during this period. Storing freshly-cut bamboo under water as is common in sap leaching procedures will increase this interval.

A number of bamboo forestry practitioners recommend managing bamboo clumps into a horseshoe cross or rotating flower configuration. In this practice, new shoots are encouraged to form at the outside of the clump, with a small access corridor maintained to allow access to the center. The inner section of the clump will contain older culms ready for harvesting while the outer expanding section is only new growth.

EXAMPLE OF HORSESHOE CROP MANAGEMENT SYSTEM

DEVASTATED BAMBOO CLUMP IN BANTUL, YOGYAKARTA AS A RESULT OF AGGRESSIVE HARVESTING POST-2006 EARTHQUAKE

ROUGH AND UNCLEAN CUTS WHEN HARVESTING BAMBOO RESULTING IN INCREASED FUNGAL ATTACK

B.3 TREATMENT

B.3.1 TO TREAT OR NOT TO TREAT

Perhaps the greatest debate amongst humanitarian workers regarding the use of bamboo is whether bamboo should be treated or not prior to use in post-disaster construction. Arguments for treatment point out the obvious advantages of increased longevity and the ensuing increase in benefit from assistance provided to the affected community, while proponents against treatment point out such factors as cost, potential environmental impacts (not of concern with borax treatments), time delays in procurement and supply, and the need for increased technical expertise.

Untreated bamboo

Cheap, fast, effective: buy it today, use it today. Biodegrades: lasts for 1-3 years depending on exposure.

Treated bamboo

Has a 20-30yrs life expectancy if correctly harvested, handled and treated, and sheltered from weather in use. Hence offers a greatly increased contribution to community resources.

The decision to treat or not treat needs to be made on a case by case basis, and will be based on a range of factors such as the forecast usage time of the structures being built and the availability of suitable skills and equipment. This decision must be based on a clear understanding of the profile of any given disaster and the suitability of bamboo treatment systems to the intended program design.

In reality, in deciding whether or not to chemically treat bamboo, the greatest defense lies in how bamboo has been handled from the moment of harvest, or even earlier, until its eventual usage in shelter construction. The best treatment systems in the world are easily undermined through simple errors in design and construction. On the other hand, completely untreated bamboo, correctly harvested, cured, transported and installed may last as long as treated bamboo which has been poorly handled.

B.3.2 PROTECTION WITHOUT TREATMENT

The most important defense for any bamboo structure, whether treated or not, is how well it is designed for protection from the elements. Untreated bamboo in direct contact with moist ground or rain may completely breakdown in less than a year, treated bamboo may fair no better.

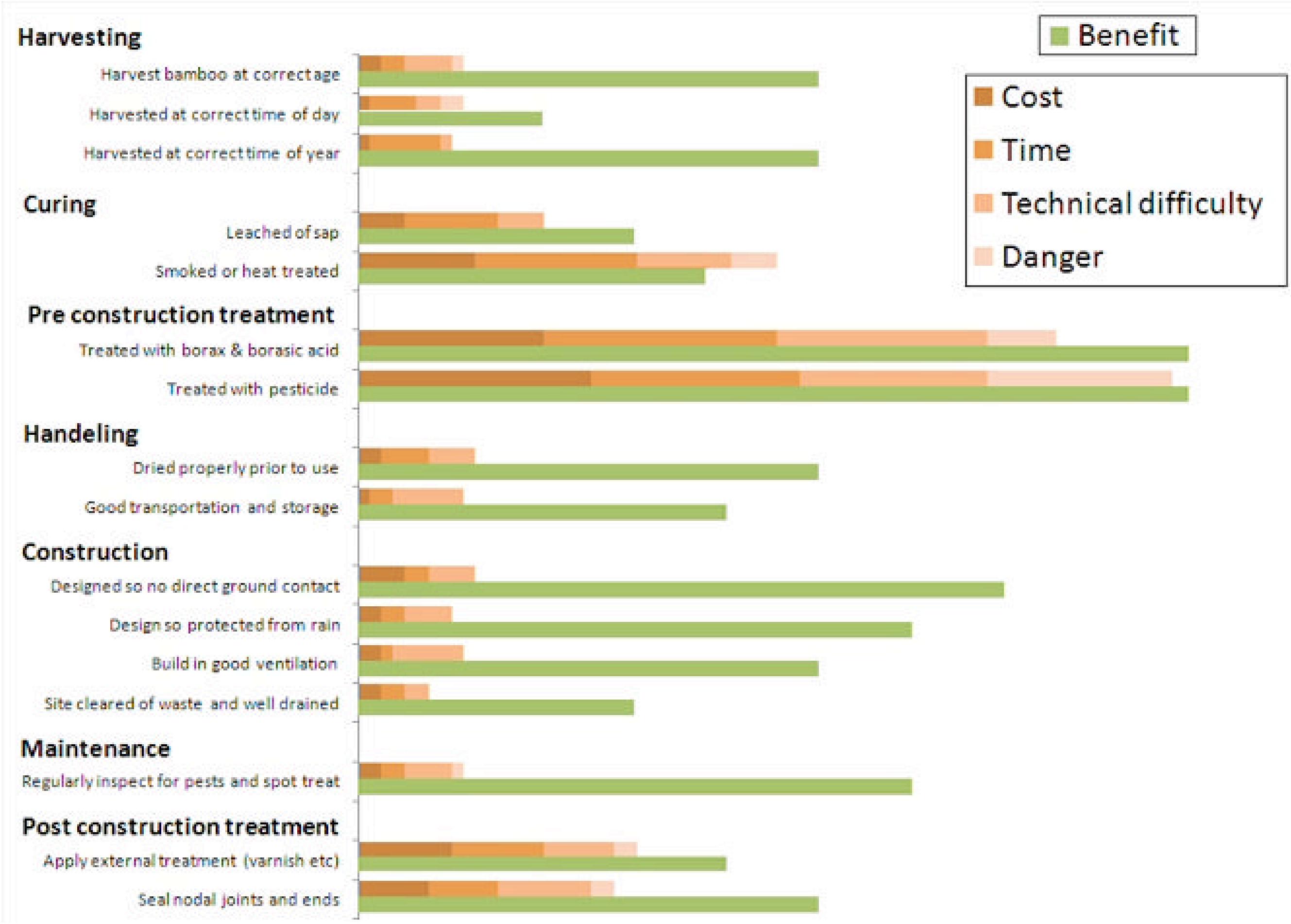
To achieve a long life expectancy from a bamboo structure it is firstly essential to follow good harvesting practice to ensure minimal sugars within the bamboo.
See *Section B.2.1 Harvesting.*

THE BEST PROTECTION FOR BAMBOO IS KEEPING IT DRY. ALLOW ADEQUATE EAVES, GOOD DRAINAGE AND KEEP BAMBOO FREE FROM DIRECT GROUND CONTACT

Key design principles:

- **Protect structure from rain**
- **Provide adequate ventilation**
- **Ensure adequate drainage**
- **Avoid direct ground contact**

COMPONENTS OF A BAMBOO PROTECTION STRATEGY



AIR CURING

Bamboo can be air-cured by leaving the branches and leaves on for two to three days after cutting. This allows the bamboo to consume the remaining sugars and starches within the culm reducing its attractiveness to pests. Branches should be kept free of ground contact throughout this period.

WATER LEACHING

WATER LEACHING

Curing bamboo through leaching the sap from within the culm removes the sugars and starches that attract most pests. This relatively simple process is undertaken as quickly after harvesting as possible because cells within the culm begin to close after 2-3 days.

Commonly bamboo is immersed in flowing water for 4-12 weeks (depending on the species), with stone weights applied to keep the bamboo fully immersed. In some parts of the world bamboo is leached in salt water as the salt offers additional pest resistance. Generally this is not recommended as salt water takes longer to penetrate the culm, and the imbedded salts also raise the hydroscopic capacity of the fibers leading to more rapid rotting.

An alternative method of leaching out saps involves standing the bamboo upright in large drums full of water for 3-4 days, to allow the bamboo plant to draw in the water and clear out it its own sap. This method can also be used as a low-tech method for injecting borax treatment.

AIR DRYING VS KILN DRYING

Bamboo that has been properly dried prior to use will have more consistent durability than bamboo dried in position. Air drying of bamboo takes around 6-12 weeks depending on species whilst slow kiln drying takes 2-3 weeks. Solar kilns that trap and store the energy from the sun, offer a low energy cost compromise of 3-6 weeks. Kiln drying may be necessary during the rainy season when bamboo may begin to be affected by mould whilst drying out.

When drying bamboo, care should be taken to provide regular support and allow sufficient space around the culms for evaporation. The rate at which bamboo can be dried varies from species to species with some species splitting more readily than others. Species prone to splitting can have their drying rate slowed down by the application of a sealant such as paint to the ends.

B.3.3 PROTECTION THROUGH TREATMENT

The durability of bamboo can be greatly extended through the application of a range of treatments, ranging from natural and low toxicity through to the use of pesticides and preservatives. Natural and low toxicity treatments are generally most suited to humanitarian projects and hence are covered here. Information on pesticide based treatments is readily available from commercial manufacturers.

NATURAL TREATMENTS: SMOKING

Smoking is one of the oldest traditional methods of preserving bamboo, with a long tradition of usage in such areas as Latin America, Japan and China. Smoke from burning timber or bamboo contains a range of preservative and protective chemicals such as creosote and furans that can make bamboo significantly less attractive to a range of pests. Additionally, the heating process kills off existing pest infiltrations whilst in some cases also partially plasticizing the lignin in the bamboo and hence increasing its durability.

There are a broad range of methods for smoke-treating bamboo, the simplest involve placing small items above an open fire for extended periods, whilst the most complex involve large stacked sealed kilns. In some traditional cultures, completed houses were sealed and smoked upon completion.

TRADITIONALLY HOUSE IN PERU, SEALED THEN SMOKED UPON COMPLETION

Research in Japan and China shows that through smoking and steam heating bamboo with a precise combination of temperature, humidity and timing, the cellulose and lignin within the cellular wall can be made to plasticize, greatly increasing the bamboo's tubular strength and durability.

Smoking bamboo over an open fire is generally only suitable for small-scale applications such as handicrafts. It is often traditionally used for preserving bamboo strings and spines used in thatched roofing. Mild ongoing open fire smoking may also be used to keep stacks of freshly cut bamboo free of pests between the time of cutting and delivery to markets.

Large scale smoking projects will require large kilns and are therefore most appropriate for ongoing humanitarian or development projects. These involve heating bamboo to between 120 and 200°C for between 12 and 48 hours depending on the species. As with most treatments, flattened bamboo sections such as those used for flooring and walling can be treated more rapidly. Punching through nodes can also improve smoke penetration. Exact times and temperatures may vary greatly from species to species and hence will require site-specific research.

In Latin America, multi-functional kilns have been established using the waste bamboo tips from harvesting for fuel whilst producing bi-products of bamboo vinegar, creosote and fuel charcoal. At the time of writing no known examples exist in Asia.

NATURAL TREATMENTS: MUD AND SALT

In many traditional communities such as in rural Indonesia, bamboo is treated by soaking for prolonged periods in either mud or sea water. Both systems require approximately one month of immersion to leach the sugar-laden sap from whole culms. Mud-based solutions offer an additional minor protection of an outer mud layer whilst the salt in sea water makes the bamboo unpalatable. Neither system is considered highly reliable or effective but may work well enough when combined with an overall protection program that includes good design etc. Note: salt solutions will increase the potential for rot by raising the wicking capacity of the bamboo.

CHEMICAL TREATMENTS: EXTERNAL

A range of external treatments can be applied to bamboo to increase its resistance to fungus and pest attack. Such treatments may include the application of kerosene, camphor, commercial pesticides and varnish or paint. The high silica content in the outer skin of bamboo commonly results in low absorption rates, with pest resistance being achieved more through the bamboo becoming unattractive to pests rather than actually being toxic. External treatments need to be reapplied at regular intervals. Once every 2-3 months is common for kerosene or once every six months for varnishes.

OIL-BASED TREATMENT PRODUCTS APPLIED TO THE SURFACE OR WOVEN BAMBOO SHEETING

In general, external treatments are not considered to be very effective, although paint or varnish can protect treated bamboo from leaching where some exposure to rain is unavoidable.

Treatments such as sump oil, bituminous tar and creosote are often used on bamboo poles inserted directly into the ground. Whilst such treatments do increase the pest resistance of the poles, most bamboo species have very low durability when in direct contact with the ground and such treatments provide far less protection than a raised footing.

PESTICIDES

A range of pesticides can be used to increase the pest resistance of bamboo. Commonly used pesticides include PCP, DDT and Dieldren. Most pesticides provide little greater protection than boron-based treatments, but have a higher cost and increased environmental and health risks. Hence these treatments are not recommended for humanitarian programming. One exception may be the growing market in commercially pressure treated bamboo products (using 3rd generation pesticides), largely from China. These products include laminated beams and flooring, which may be appropriate for more industrial humanitarian applications.

BORON-BASED TREATMENT SYSTEMS

The most common and well-documented bamboo treatment systems involve dissolving a combination of borax and borasic acid in water in concentrations of around 5-10% and then soaking the bamboo in the liquid until the solution has penetrated completely throughout the bamboo. Penetration time varies greatly depending on the system. Borax is a relatively harmless compound whose minuscule particle size allows it to easily penetrate throughout bamboo when dissolved.

Borax and borasic acid are naturally occurring boron-based compounds commonly available as sodium borate, sodium tetraborate, or disodium tetraborate. A common commercial product is Tim-bor. Borons are supplied as a white powder consisting of soft colorless crystals that dissolve easily in water. Bamboo treatments generally combine a mixture of boron and borasic acid for pest resistance with the acid providing an added advantage as a fire retardant.

BORON CRYSTALS

There are a wide range of well-documented systems for embedding borax and borasic into bamboo. It is important to weigh up the relative advantages and disadvantages of each system in relation to the program you are planning. Some systems are better suited to long-term mass production whilst others are better suited to short-term community-level production.

Borax treatment systems can be broadly broken into two groups: pressure feed and soakage-based systems. Pressure feed systems, such as the well-known gravity-fed Broucherie method, utilize the fluid transportation system of the plant, by attaching a pipe to one end of the culm and pumping borax solution through the plants vascular system. Pressure treatment methods are conducted within the first few days of harvest before cellular collapse sets in. These systems offer the added advantage of purging the remaining sap from the culm, thus reducing the need for leaching, with the associated disadvantage of needing to be undertaken soon after cutting. Perhaps the best documented pressure-fed systems is the modified Broucherie method in which a pump is used to force solution from the thick end of a culm. A lesser known system that is better suited for village level production has been developed by ARTI in India, using hand pumps attached to the thin end of the culm.

Soakage systems are generally simpler though slower than pressure fed systems, involving the immersion of bamboo for long enough that the borax solution penetrates throughout the culm. Soakage systems require the punching out of nodes or the drilling of holes between nodes to allow complete penetration of the borax solution. The simplest soakage solutions involve soaking for 3+ days, dependent on the species. Perhaps the best documented system in Indonesia is the Vertical Soak Diffusion (VSD) system as practiced and documented by the Environmental Bamboo Foundation, C.V. Indobamboo and P.T Bambu in Bali. For VSD, bamboo culms are stood vertically with all nodes except the bottom node punched through. The culm is then kept filled with borax solution for a number of days until full dissipation has occurred.

Treatment Type	Physical/ chemical	Best practice (horizontal) vertical)	P	E	T	D	Time for treatment	Durability (1-10, approx years)	challenges	advantages	opportunities	Cost (1-10)	Accessibility of technology (1-10)	Hazards posed by treatment process (1-10)	Amount of resources needed (1-10)
No treatment	P	H		Y				2	Durability	Quick, low cost		1	10	1	1
Seasoning (moving water)	P	H	Y			Y	3 months	4	Process time, lifespan in the building, availability of water source	Low cost, easy technology		2	8	1	2
Heat treatment	P	H	Y		Y	Y	10 min	4				2	8	2	2
Fuming	C	H	Y		Y	Y	1-2 days	6+	Equipment intensive			4	6	2	6
Smoking	P	H	Y		Y	Y	1-2 days	5+	Equipment intensive			3	6	2	6
Surface coating	P	H	Y	Y	Y		10 min	3				4	7	5	3
SQ treatment	C	V	Y			Y	30 min	7(+)	Mechanical process to learn	Removes sugars completely		5	4	6	8
Vacuum treatment	C	V	Y			Y	30 min	10	Equipment intensive			8	3	6	10
Soak treatment; vertical	C	V	Y		Y	Y	1 day	8	Often still attacked by insects			5	6	6	7
Soak treatment; horizontal	C	V	Y		Y	Y	3 days	6+	Often still attacked by insects	Easy process		7	6	6	6
Transpiration	C	V	Y		Y	Y	2 days	6	Often still attacked by insects	Easy process		6	6	6	6
Combination			Y			Y		10+	Costly, multiple operations so equipment intensive			10	6	6	10

B.4 LOGISTICS AND HANDLING

The care with which bamboo is handled and transported from the moment of cutting to final placement will have a direct bearing on the usable lifespan of the end product.

TRANSPORTATION AND HANDLING

The need for care when transporting and handling bamboo grows in importance with the duration and complexity of the trip. Bamboo should be:

- Covered during transportation to prevent excessive drying and splitting of uppermost culms.
- Protective sheathes should be used between ropes and bamboo to prevent damage.
- The bottom layer of bamboo should be checked carefully for crushing, to determine maximum weight loading. The lightweight nature of bamboo means this is generally not a problem.

Trips involving transportation by sea need to include adequate steps to prevent mould damage. Bamboo packed inside containers should include some form of moisture absorption strategy, the simplest of which is the inclusion of sacrificial sacks of lime or cement.

When loading and unloading bamboo, care should be taken to ensure bamboo is not thrown to the ground as this will cause cracking. Such cracks may not be visible at time of unloading but will broaden as the bamboo dries in situ, weakening the final structure.

The waxy layer and fungus on the outer layer of bamboo may cause skin irritation. Workers handling bamboo continuously should be provided with gloves.

STORAGE

Bamboo should be stored:

- Free of ground contact to prevent pest infestation.
- Stacked horizontally with regular support at 2-3 node intervals to prevent warping.
- Under shade to prevent undue cracking.
- With adequate air flow around culms to prevent mould.

Is community-based procurement possible?

Direct procurement by the community may inject up to 8 times as much funds and can reduce unnecessary storage and handling. Consider logistics & procurement training.

Storage yards should be:

- Kept clean and free of sawdust and cutting waste to prevent pest infestation.
- Stock should be rotated regularly through the yard ensuring no stock is left for prolonged periods. If storing for more than 1-2 weeks bamboo should be turned over regularly to ensure even drying and reduce the potential for mould growth or pest infestation.

Section C

Building

Key Points

- Bamboo is a very distinct construction material with its own unique set of positive and negative characteristics. A good understanding of the fundamental differences between bamboo and other construction materials is essential to the implementation of successful bamboo projects.
- How well a bamboo building is designed, constructed and maintained will greatly affect the durability of the structure.
- Woven bamboo sheeting provides a cheap efficient resource for walling and flooring material. Communities need to be engaged to define quality criteria.
- Working with communities to define ongoing maintenance procedures can greatly enhance the life expectancy of any bamboo structure.

C.1 DESIGNING A PROGRAM THAT USES BAMBOO

Having already made the decision to use bamboo, a number of key questions should be asked prior to commencing design of the program:

How much bamboo will the program need and how will this impact the affected community's resources?

- Can the program incorporate replanting?
- Can procurement be diversified?

Approximately how long are the buildings expected to be inhabited for?

- Does the bamboo need to be treated? If so, which system is most appropriate?
- Is the design durable enough for the time frame?
- What jointing system is appropriate for the time frame?

What future risks are the buildings likely to face and how can we mitigate those risks?

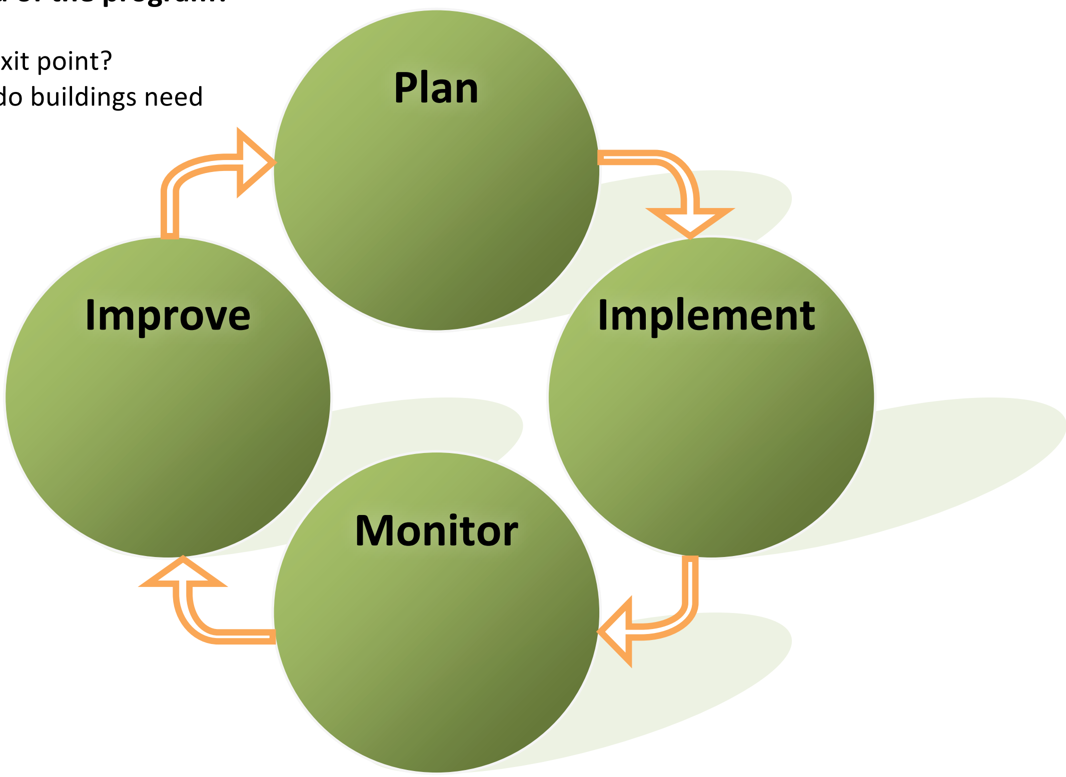
- Adverse weather such as intense rain, cold or heat?
- Future climatic events?

What skills and resources does the community have to build and maintain the structures?

- Will the program need to include capacity building or training?
- Will the program need to include supply of tools or ongoing support?

What is the time period of the program?

- What is the exit point?
- How rapidly do buildings need to be built?



C.2 DESIGNING WITH BAMBOO

Designing and building in bamboo requires an understanding of different design and construction principles to those used with other common building materials such as timber, steel, concrete or bricks.

In length, bamboo provides high tensile and compressive strength, whilst its tubular structure means that it is much weaker across its width where it is prone to crushing, except at nodes. Bamboo's flexibility across its length allows for high levels of shock absorption, whilst also providing real potential for the design of curved elements held in tension. Bamboo poles in construction will support high loads as long as the building is constructed so the pole cannot buckle.

C.2.1 COMPARATIVE CHARACTERISTICS OF COMMON CONSTRUCTION MATERIALS

	BAMBOO	TIMBER	STEEL	MASONRY
STRENGTH	• Tensile strength of mild steel • Weak in side compression	• Strong in side compression, tension and length	• Weak in lengthwise compression • High tensile strength	• High compressive strength • Low tensile strength
DURABILITY	• Low durability (1-2 years) • Unless cured or treated (10-25years)	• Durability dependant on species and exposure (from 2-3 years to 20-30 years)	• Highly durable (10-30 years)	• Highly durable (20-50 years)
FLEXIBLITY	• Extremely flexible, particularly in split sections	• Limited to small sections or complex steam bending	• Highly flexible: can be formed to whatever shape required	• Inflexible • Rigid structure
JOINTING	• Low technology • Bolting or pegging • Lashing or tying • Nailinglimited • Simple and low cost	• Medium level technology • Screwing, nailing and bolting • Medium cost	• High technology • Screw, weld, rivet • High cost	• Mortar • Low cost
SPPED	• Extremely fast • 1 week per shelter	• Medium • 1-3 weeks per shelter	• Rapid • 1 week per shelter	• Slow • 4-6 weeks
AVAILABILITY	• Available in large quantities across most disaster-prone tropical areas	• Globally diminishing resource • Environmental concern in many disaster-affected countries	• High availability although may frequently need to be imported to area	• Highly available in most areas • Variety of options

COST(BASED ON24M^2 SHELTER)	• Extremely low cost • $100-300	• Medium cost • $500-1000	• High cost • $2000-5000	• Medium to high cost • $1000-5000

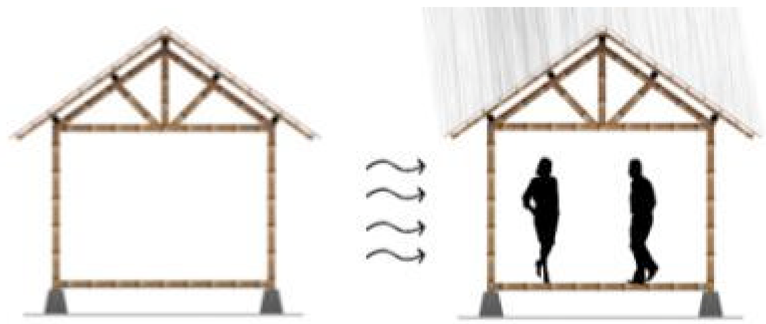
C.2.2 DESIGN PRINCIPLES

A number of key design principles need to be considered when planning a project in bamboo. To understand these principles it is important to first understand some basic principles of construction.

NOTE: This manual does not intend to be a design book for engineers, but rather aims to provide guidance for humanitarian workers to ensure they have asked the correct engineering questions and incorporated simple good practice into their work. Although in general, simple emergency and transitional shelter solutions do not require complex engineering, it is clearly best practice to ensure that such mass programs have been checked by a skilled (preferably local) professional. Where such resources are not available consider using plans that have already been designed and tested or seek more detailed technical advice. See *Section D.1 Further resources.*

LIVE AND DEAD LOADS

Buildings are exposed to two main types of forces, dead loads and live loads. Dead loads are the static forces that apply such as the weight of the roof bearing down on the structure, whilst live loads include the dynamic changing loads that a building will have to cope with over its lifespan, such as the weight of the changing number of people inside it, wind forces, pressure caused by ground movement in an earthquake or water pressure in a flood.

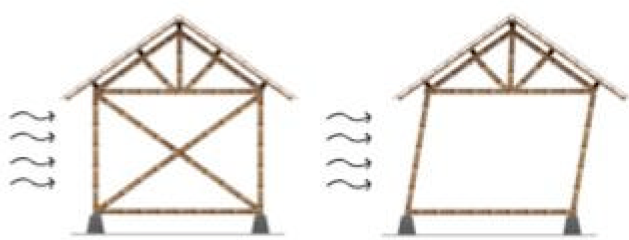


THE DEAD LOAD OF A BUILDINGS WEIGHT VS THE LIVE LOAD THAT A BUILDING EXPERIENCES DURING USE

When designing a building, it is essential to consider the range of live loads the building will be exposed to. This is of particular importance in when working in disaster prone areas where the likelihood of floods, high winds or earthquakes may greatly increase the stress loadings that a building may have to cope with.

MOMENTUM AND BRACING

When buildings suffer sudden loads, such as those experienced in an earthquake, they may twist or warp. Such movement, combined with the mass of the structure, can create high levels of momentum, greatly increasing the effective weight or force load that is applied across the building. Much of this force will be transferred to the joints of the building, making them



EFFECT OF WINDLOAD ON BUILDINGS WITH AND WITHOUT BRACING the weak point in most structures. This is particularly so in the case of bamboo. The inclusion of bracing across in all planes of the structure reduces the potential load on joints.

DESIGN FOR ADAPTABILITY, REUSE, MAINTENAINCE AND DECONSTRCUTION

When designing any building, consideration should be given to the future potential usage and life cycle of the building. Temporary shelters by their very nature have a limited life in the original design format. It is important to consult with communities about how such structures may be used in a longer time frame and take the possibilities into consideration at the design stage. In many cases such as the Yogyakarta earthquake response, transitional shelters went on to perform a range of roles such as shops, stables, kitchens and spare rooms. Many shelters were also dismantled for reuse in the permanent home. Temporary shelters also often become the core for a permanent construction.

Design for deconstruction and reuse can be achieved through the use of non permanent joints such as bolting and lashing. Walls can be designed for future masonry roof loads even though an agency is only supplying tarpaulin roofing. The decision to treat bamboo for framing may encourage the reuse of some elements or even the whole shelter in permanent construction.

DESIGNING FORBEST NODAL PLACEMENT

Nodes are the strongest point in the cross section of the culm of bamboo, hence the closer a joint is to a node the stronger the joint will generally be. As a rule of thumb ideally joints should be no further from a node than the width of the bamboo sections that are being joined.

In saying this, it is important to recognize that fastidiously selecting bamboo for exacting nodal placement, although creating a stronger structure, may consume much more time and potentially more bamboo. Hence it is important to focus on joints of higher structural priority, ensuring nodes occur as close as possible to these joints.

A number of strategies can be engaged to improve joint strength through better nodal placement:

Sheathing

Where joints do occur between nodes it is possible to strengthen the joint by using sheathes or fishplates to spread the load across the spacing between nodes.

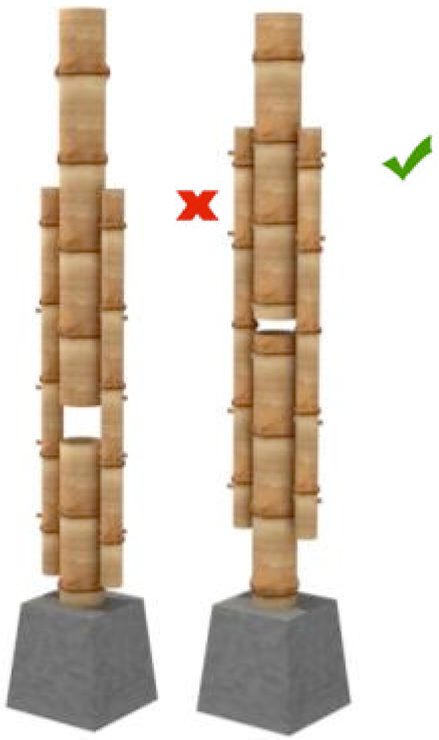
DETAIL: Top plate with fish-plate where posts intersect

Humanitarian bamboo

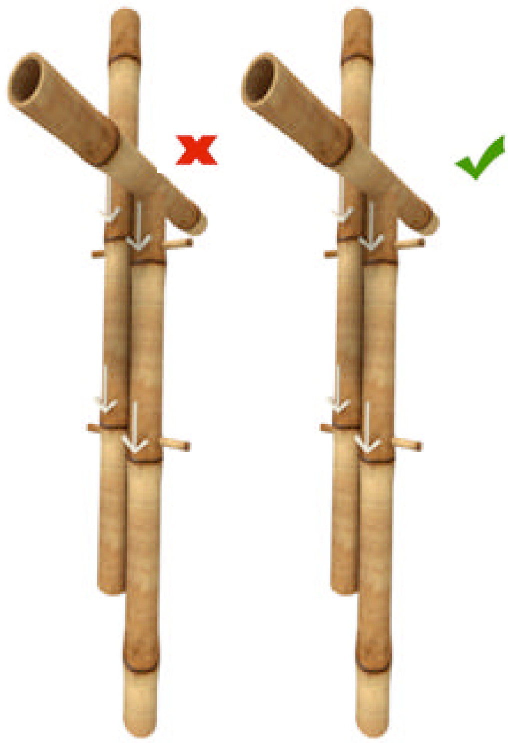
Bearing onto nodal joints

Joint designs can take advantage of the strength of nodes by bearing more directly onto them. Note the two diagrams to the right where pins are correctly located close to nodes.

Note: When analysing the diagrams below, consider where the downward forces apply.



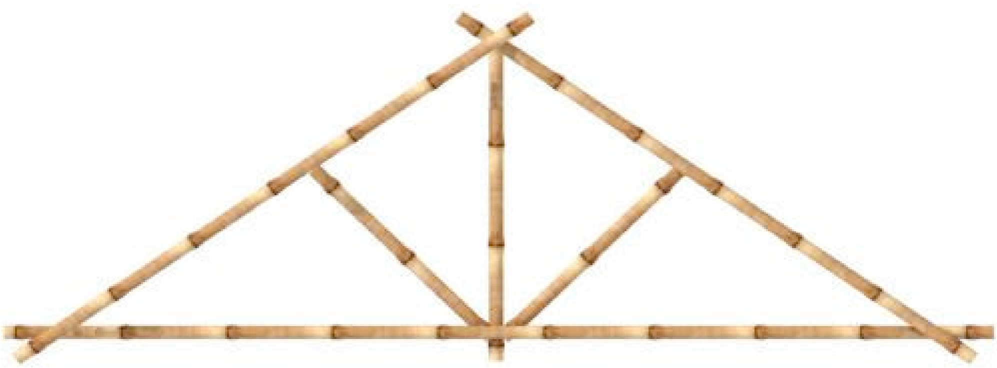
SACRIFICIAL FOOTING



JOINING A FLOOR JOIST OR TOPPLATE TO A COLUMN

The nearest node past the joint

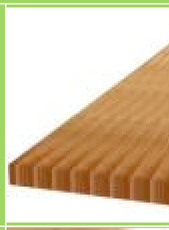
Unlike when working with timber, joints can often be greatly



ROOF TRUSS WITH JOINTS RUNNING TO THE NEAREST NODE strengthened simply by allowing each member of the joint to continue past the joint to beyond the nearest node before cutting.

C.3 CONSTRUCTION

The following chapter outlines the broader concepts behind construction in bamboo covering jointing systems, framing, walling, flooring and roofing. There are many options available for each of these components and the choice of which solutions to use is highly dependent on the needs and abilities of the affected community. Hence this chapter does not focus on providing any one solution but rather an overview.

GLUEING		
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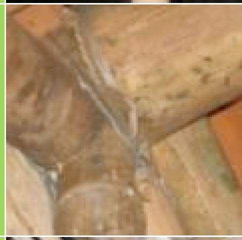
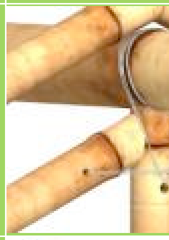
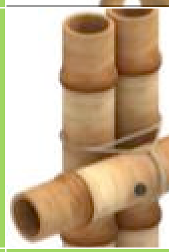
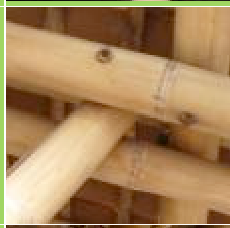
WIRED		
TIED		
PEGGING		
PEGGED & TIED		
BOLTING		SKET
FILLED & BOLTED		SKET

C.3.1 STAGING CONSTRUCTION

In planning the construction of any dwelling, a number of issues should be considered:

Set-out and site preparation

- Is the drainage off the site adequate?
- Access to sanitation
- Safety from remnant buildings
- Safety from further events such as flood and landslide
- Consider impact on future permanent construction

Foundations and footings

- Is there adequate tie-down for windload and earthquakes in the area?

Framing

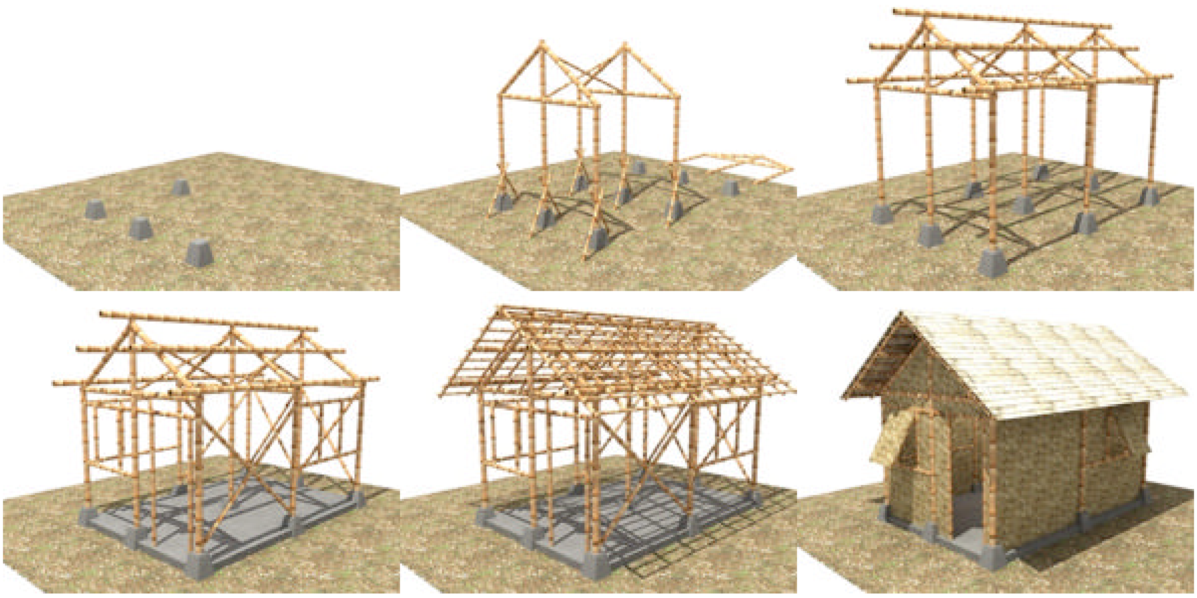
- Ensure adequate temporary bracing during construction as well as permanent bracing
- Is the frame strong enough for future roof loads and live loads

Roofing

- Sufficient eaves to protect walls

Cladding, doors and windows

- Is there adequate security for return to work?
- Is there adequate ventilation and privacy?



C.3.2 JOINTING SYSTEM TYPES

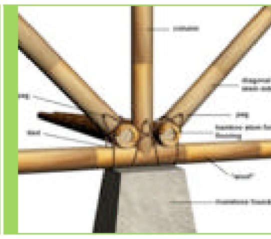
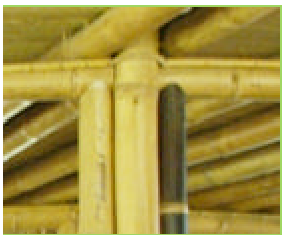
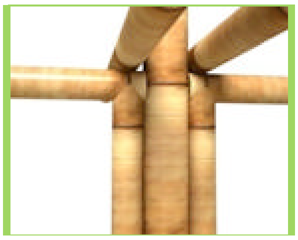
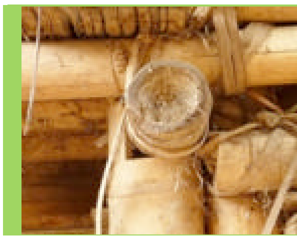
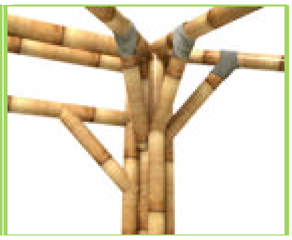
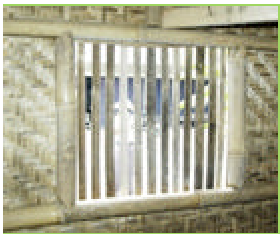
Different jointing systems offer differing relative merits (see below for comparison). The choice of jointing system should be based on the relative importance of these characteristics to the project at hand, as well as taking into consideration local skills and construction knowledge.

Relative merits of bamboo jointing systems

Best → Worst

Joint Type	Notes	Strength				Usability			Cost		
		Durability	Rigidity	Strength	Flexibility	Ease of use	across joints	Speed	Low labour	Cheap material	Few tools
Bolts	• Crushing of the bamboo must be avoided • Only as strong as the bamboo they pass through • Best when braced in all directions	5	5	5	2	3	4		2	2	2
Fill & bolt	• Creates a very rigid joint • Particularly well suited to footing connections and industrial loads	5	5	5	2	2	3		1	1	1
Glue	• The outer skin of bamboo is highly resistant to glue whilst the inner layers glue well • Particularly suited to longitudinal joints	4	4	4	1	2	1		2	3	3
Rubber strap	• A range of re-used rubber (such as old inner tubes) can be used, but beware that they may break down under UV exposure • Heavily dependent on how it is attached to the bamboo (often poorly nailed) • Hard to find consistent supply	3	2	2	5	4	4		4	4	4
Nails	• Prone to splitting, particularly in running species • Pre-drilling or chiselling will reduce tendency to split • Best suited to temporary structures and clumping species	2	1	2	3	5	4		5	5	5
Pegs&rope	• See separate notes under pegs and ropes • Labour-intensive, strong and low tech	4	3	4	4	2	5		2	3	2
Pegs (dowels)	• Commonly may be timber or bamboo • Require pre-drilling • Strength dependent on node to joint placement	3	2	3	3	3	4		3	4	3
Plywood & bolts	• Commonly for trusses or structural load • Bolt locations should still align to nodes	5	5	5	3	2	4		2	1	1
Rope or rattan	• Often well known at village level • A range of materials can be used: seek local advice for traditional materials	3	2	3	5	3	4		4	5	5
Screws	• Prone to splitting - requires pre-drilling • Best suited to joining bamboo to timber	2	2	2	2	3	4		4	4	4
Wire	• Prone to rust at ends and knots • Can be improved by protective painting • Will 'dig in' under high load	3	3	3	4	4	5		5	5	4

C.3.3 EXAMPLES OF COMMON JOINTS

FOUNDATION			Photo	
POST TO BOTTOM PLATE JOINT				
POST TO TOP PLATE				
LINTEL DETAIL				
BRACING DETAIL		SKETCH	Photo	SKETCH
RAFTER TO TOP PLATE				
ROOFING TO BATON		SKETCH	Photo	SKETCH

C.3.4 WALLING

In designing simple transitional or emergency shelters from bamboo, a range of walling materials are available. This chapter introduces the key concepts regarding the main walling options and provides pointers on key issues to be considered.

Key considerations

- **Is the walling material that is being considered readily available in the quantity required?**
- **What effect will bulk procurement have on the local and regional environment?**
- **What is the capacity of the local community to supply or create their own walling materials?**
- **Is the chosen walling materials must be culturally and climatically appropriate?**
- **Can the material be replaced or upgraded when it wears out?**

A RANGE OF BAMBOO CLADDING ON TEMPORARY SHELTERS

Material and lifespan	Advantages	Disadvantages	Notes
Plastic sheeting *6-18 months*	• Rapidly deployed and erected • Low cost • Water- and wind-resistant • Low impact on local natural resources	• High environmental cost • Little or no economic input • Low community participation • Short lifespan • Can't be repaired or extended easily by the community	• Standard of sheeting used is important. See plastic sheeting guidelines • May require different plastics for different climates
Flattened bamboo *2-3 years if protected from the rain and ground contact*	• Easily manufactured • Rapidly erected • Requires few specialist tools • Well-ventilated: good for hot humid climates • Biodegradable natural material • Community livelihood activity	• May not provide adequate privacy • May not provide adequate rain and wind protection in cold climates • Limited life expectancy • Increased load on bamboo resources (consider alternative species)	• Must be culturally appropriate to the area • May require particular species • Flattened bamboo is easily leached or treated to increase durability
Woven Bamboo *2-3 years if protected from the rain and ground contact*	• Increased wind and rain protection over flattened sheeting • May support local handicrafts industry and strengthen economic recovery • Livelihoods opportunity for the affected community	• More labour intensive manufacturing than flattened sheeting • Often difficult to procure in bulk as is commonly produced at village level • Highly variable product, must negotiate minimum standards with affected community	• Sheeting woven from outer skin of bamboo is more durable but coarser • Many styles and patterns exist, community consultation is essential to select appropriate standards
Composite Sheeting *Indefinite - 5-20 years, depending on quality*	• May provide insulative capacity • Livelihoods creation project • May be highly durable depending on glues and construction system • May be structural • May be plasterable or paintable, creating permanent structures	• Complex to produce • Time consuming to produce • May require extensive training or capital expenditure on equipment	• Probably not suited to rapid response • May require prepositioning • Worth considering for ongoing humanitarian situations in colder climates
Cement sheeting *Indefinite: 5-20 years, depending on quality*	• Highly durable • Can be plastered or painted • Easily fastened, repaired and renovated • Relatively cheap permanent material	• Extremely hard to ensure asbestos-free sheeting in many developing countries (particularly in Indonesia) • Expensive, heavy and slow to procure compared to bamboo products	• Asbestos content is a major concern whenever dealing with cement sheet in Asia as it is not banned in most Asian countries.
CGI Sheeting *Indefinite: 5-20 years, depending on quality*	• Highly durable • Walls only require a very light gauge material • Relatively cheap permanent solution • Easy to procure in bulk	• "Tin shed" feel • Energy-intensive solution • High environmental impact at source and creation • Relatively expensive compared to bamboo and other natural materials	• High thermal conductivity can be problematic in extreme climates. • Difficult to attach easily to bamboo framing
Timber cladding *Indefinite: 5-20 years, depending on quality*	• Durability dependant on species, but can be highly durable • Easy to work with, repair, extend and maintain • Often well known as a material by the affected community	• Potentially high environmental impact • Difficult to procure in bulk • Requires expertise in specifying and procuring	• See Humanitarian Timber guidelines
Alternative natural materials *Dependent on material*	• Wide range of potentially appropriate materials • Potentially low environmental impact • Often supports local procurement or creation by affected community, speeding up economic recovery	• Often difficult to procure in bulk • Can be difficult to measure the environmental impact • Often outside the sphere of knowledge of professional humanitarian workers so may require technical support	• Worth considering in longer term humanitarian situations to reduce the load on other resources • May include such products as rattan, jute, leaves, grass, bark etc.

PLASTIC SHEETING

During the emergency phase of many humanitarian responses, large quantities of plastic sheeting are frequently distributed as emergency shelter materials. When commencing a temporary shelter project in bamboo, it may be appropriate for this material to be used as temporary walling until a more permanent solution can be found. One solution is the planning of a staged intervention program in which an initial plastic sheeting distribution is then supplemented with bamboo for building a shelter frame, followed by roofing materials, at which point plastic sheeting is used or walls, finally followed by a top-up of more durable walling materials. Such programs assist communities on their path of recovery from shelter insecurity back to permanent shelter in affordable and manageable stages.

Plastic sheet walling on transitional shelter in Sewon, Indonesia

FLATTENED BAMBOO

Bamboo culms that are simply flattened provide a common and easy solution to both walling and flooring. Normally communities select particular species for this application based on the ease of splitting and flattening, along with a desire for a suitably strong wall thickness and a relatively wide flattened panel. Community consultation is essential in specifying the appropriate bamboo for this task.

Some communities may perceive flattened bamboo as inadequate for walling due to lack of privacy or excessive ventilation for the climate.

FLATTENED BAMBOO SHEETING WALLS

The increased exposed surface area in flattened bamboo makes it ideal for treatment through leaching or borax solution to increase its life expectancy in construction.

WOVEN BAMBOO SHEETING

A huge diversity of woven bamboo sheets exist across the world. This diversity reflects not only the intended use of the product but also the characteristics of the bamboo being used and is often an expression of the culture or beliefs of the community producing the sheeting.

Thinner sheets utilising the inner core of the culm of bamboo are commonly used for interior walls and floor mats, while sheets woven from the outer skin offer high pest and rain resistance and are more common as outdoor cladding materials. Coarse woven sheeting may be used for animal enclosures or fences.



When procuring woven sheeting it is critical to involve the affected community in detailing minimum specifications. A range of cultural, historical, religious and climatic factors may influence what a community feels is appropriate in a woven sheeting. In cold mountain climates, tightness of weave may be critical whilst in coastal communities, a loose weave but a more durable outer skin may be more appropriate. In colder climates, woven sheeting walls can be also plastered with cement, newspaper, plaster or mud to make it wind proof.

C.3.5 FLOORING

This section is not yet finished. Updates will be made available on the website.

C.3.6 ROOFING

Material	Advantages	Disadvantages	Notes
Plastic sheet	• Rapidly deployed • Rapidly erected • Low cost • Water and wind resistant	• High environmental cost • Little or no economic input • Low community participation • Short lifespan • Can't be repaired, extended easily by the community	• Standard of sheeting used is important. See plastic sheeting guidelines • May require different plastics for different climates
Thatching	• High community participation • Biodegradable and renewable • Boost local economy • Cost effective, insulative	• Difficult to procure in bulk • Requires specialist knowledge on selection and specification • High fire risk in dense applications • Potential deforestation	• Well suited to remote areas, less in urban/peri-urban • Large scale humanitarian shelter plans with thatching may rapidly deplete local resources
Corrugated iron	• "Waterproof top to bottom" • Well-suited to bulk procurement • Can be very durable	• Accentuates heat • Rusts • May prove hazardous if poorly fastened in high wind areas • Limited impact on local economy • High ecological cost • Expensive	• Decision must fit local community cultural practice • Sheet gauge is a key issue affecting durability, as lightweight sheets are commonly available • Appropriate tools and safety equipment
Roof tiles	• Highly suited to local small scale production • Can often be procured at a community or regional level • May be suitable as a top up program using recovered tiles • Easily moved from temp to permanent shelter • Relatively low cost	• As a patchwork of waterproof elements tiles provide a less reliable protection than continuous roofing materials • Require a minimum pitch of 12+ degrees • Increased danger during building collapse	• The choice between cement and clay tiles should be made based on available aggregate and soil • Quality varies dramatically based on production procedures • Environmental impact of fuel source must be considered for clay tiles
Cement sheeting	• Light weight • Easily transported • Can be made locally or procured in bulk • Easy to work and handle	• Many countries in Asia continue to sell highly carcinogenic asbestos-reinforced sheets. In under-regulated countries "asbestos free sheets" may well still contain asbestos. • Safe handling equipment and tools should be included.	• The use of cement sheeting by NGOs may result in increased uptake of asbestos sheeting by the surrounding population. To avoid this, strong public messages material should be included with any program using cement sheet, or else the product should be avoided.
Bamboo	• Well-suited to remote areas with plentiful bamboo supply • Cost effective • Suited to local procurement and job creation	• May consume excessive bamboo • Simple lapped sections are not very durable, thatching and shingles are much more durable • Smoking may improve durability, although borax treatment won't	• A wide range of bamboo roofing solutions exist. These include: • Lapped bamboo sections • Bamboo shingles • Bamboo strip thatching

Section D

Support

1. Further resources
2. Further uses of bamboo in humanitarian programming
3. Bamboo in Indonesia

Key Points

This document offers only a brief introduction to the use of bamboo in humanitarian shelter programming.

To undertake a large scale program it will be important to seek more detailed information specific to the context of the project being undertaken. This section of the guidelines supplies some additional resources or linkages to those resources.

There are a range of other uses for bamboo that may be worth considering in humanitarian programming such as composite panels and laminated bamboo beams.

Understanding where bamboo resources are available may influence decisions regarding the suitability of using bamboo in any given humanitarian response.

D.1 FURTHER RESOURCES

A range of further resources are available from the Humanitarian Bamboo website at www.humanitarianbamboo.org. If you have an additional resources or links that you believe may be of value to other humanitarian practitioners please contact the project through the website.

Resources available on the website include photographs of bamboo projects, bamboo reference documents and links.

D.1.1 INTERNET RESOURCES

BAMBOO-RELATED

- Global organisations
  - www.inbar.org
- Bamboo experts in Indonesia
  - www.bamboofoundation.org
- Bamboo plant stock supplies in Indonesia
  - www.bambunusaverde.com

SHELTER-RELATED

- www.humanitariantimber.org
- www.sheltercentre.org

D.1.2 ORGANISATIONS

A broad range of organisations exist that may be able to supply additional information to humanitarian practitioners on the use of bamboo. These include:

INDONESIA

- Environmental Bamboo Foundation (EBF), Bali
- C.V. Indobamboo, Bali
- P.T Bambu, Bali
- Department of Engineering and Architecture, University of Gaja Mada, Jogyakarta
- Bandung Institute of Technology, Indonesia
- Department of Public Works, Building Research centre, Bandung

INTERNATIONAL

- INBAR, The International Network for Bamboo and Rattan

D.1.3 BOOKS

Here is a short list of some of the books used in researching this manual.

INBAR, and Government of Mizoram, 2001. *Affordable Bamboo Housing in Earthquake Prone Areas: An International Workshop Organised by CBTC, Government of Mizoran, and International Network for Bamboo and Rattan*. India: CBTC.

AIS, Asociación Colombiana de Ingeniería Sísmica, 2001. *Manual de construcción sismo resistente de viviendas en Bahareque Encementado*, Bogota: Editorial Carrera.

Farrelly, David, 1984. <u>The Book of Bamboo : A Comprehensive Guide To This Remarkable Plant, Its Uses, and Its History</u>. San Francisco: Sierra Club Books.

Janssen, Jules, 2007. *Building With Bamboo: A Handbook*. Warwickshire: ITDG.

Stulz, Roland, and Kiran Mukerji, 1993. *Appropriate Building Materials: A Catalog of Potential Solutions*. Switzerland: SKAT Publication.

Von Vegesack, A.; Vélez, S; Kries, M. and Vitra Design Museum, 2000. *Grow Your Own House.* Vitra Design Museum.

Otto, F, 1985. *IL 31 Bambus / Bamboo.* Stuttgart: The Institute of Lightweight Structures.

India: BMTPC. Building Materials and Technology Promotion Council (BMTPC). *Bamboo: a material for cost effective and disaster resistant housing*. New Delhi: Ministry of Urban Development & Poverty Alleviation.

National Mission on Bamboo Application, 2004. *Training Manual : Building with Bamboo.* New Delhi: Tulika Print.

Environmental Bamboo Foundation, 1994. *Petunjuk Kerja Pengawetan Dengan Sistem Boucherie*. Jawa Barat: Yayasan Bambu Lingkungan Lestari.

D.2 FURTHER USES OF BAMBOO IN HUMANITARIAN PROGRAMMING

D.2.1 PREPOSITIONING TREATED BAMBOO STOCKS

Many humanitarian response agencies have prepositioned stocks of tarpaulins, tents or other emergency shelter materials in strategic locations across disaster-prone regions. Treated bamboo components for emergency transitional shelters could potentially be stored in such a manner.

D.2.2 DESIGNING WITH CURVED ELEMENTS

One unique aspect of bamboo when compared to timber is its capacity to be bent and used in tension. This is particularly true of small diameter and split sections of bamboo or bamboo that has been steam heated.

Unfortunately, little investigation of the potential for this in humanitarian response appears to have been undertaken. Bangladesh transient workers' shelters constructed much like tunnel tents as used by the Red Cross and other agencies, or woven baskets, reminiscent of dome tents, both point to potential areas for future research.

Advantages such as low use of material and rapid construction offer real potential for cheap and effective emergency shelter.

Bangladesh, transient workers huts

Woven bamboo basket for chickens, showing bamboo's potential for emergency dome shelters

Temporary storage hut made from bamboo and jute

D.2.3 BAMBOO COMPOSITE CONSTRUCTION PRODUCTS

The excellent gluing properties of the inner fibers of bamboo make it ideally suited to the production of a wide range of composite products. Many of these products may be ideally suited to humanitarian shelter or developmental housing projects, including:

- Parquetry flooring
- Laminated beams
- Woven bamboo tiles
- Bamboo reinforced concrete
- Bamboo-based fibrocement
- Bamboo polystyrene composite panels
- Bamboo plaster panel construction

Much research on bamboo composites has been undertaken in Indonesia by leading universities and research institutes. One example of this research is the work conducted by the Department of Public Works Research Center in Bandung, where Professor Purwito has produced a number of composite materials and model houses. Similar levels of research have also been conducted at Bandung Institute of Technology, UGM and Muhammadiyah in Yogyakarta and EBF in Bali amongst others. Much of this research offers real potential for use by the humanitarian sector in Indonesia.

DETAIL 1, 2& 3: DPU BUNDUNG RESEARCH CENTER: BAMBOO FIBRE POLYSTYRENE COMPOSITE PANEL, HOLLOW CORE BAMBOO PANEL, BAMBOO PLASTER HOUSE. DETAIL 4: BAMBOO RESIN COMPOSITE TRUSS, INDIA

BAMBOO WATER TANKS AND PIPES

Bamboo has long been used for a range of plumbing and irrigation purposes. A number of successful designs exist within Indonesia for the creation of water tanks using bamboo as their base. These include bamboo-reinforced concrete tanks designed by Diang Desa, and tarpaulin and bamboo designs by Oxfam GB's PRIME team. These temporary water storage solutions are easily erected on site by local communities, minimising transportation storage and procurement costs.

BAMBOO HANDICRAFTS AS LIVELIHOODS

In many tropical communities the manufacture of handicrafts from bamboo is an important source of livelihood. Bamboo craftwork is often produced through small home based industries supplying supplemental or fulltime income to those who may not have access to more mainstream employment.

Common bamboo handicrafts include woven matting, baskets, brooms, tool handles, plates and bowls, and cutlery and chopsticks.

The integration of a woven bamboo sheeting livelihoods recovery program for walling and floor mats in emergency shelters may assist bamboo handicrafts communities in an early return to productive income.

BAMBOO AS FOOD AND FODDER

Bamboo shoots are a highly nutritious food crop, whilst leaves of a number of species can provide fodder for cattle and goats. Bamboo shoot farming may form an appropriate livelihoods project or a valuable component of a bamboo plantation and replacement strategy.

D.4 DISTRIBUTION MAPS OF BAMBOO IN INDONESIA

The Humanitarian Bamboo project hopes to develop four separate maps that show areas of availability of bamboo species suitable for use in humanitarian shelter programs across Indonesia, broken up by usage type:

- Map 1 Species suitable for structural poles
- Map 2 Species suitable for general structural use
- Map 3 Species suitable for woven bamboo sheeting
- Map 4 Handicraft species

Maps will provide:

- Shading indicating how commonly available the material is in each area
- Names of the most common species that are suitable for each area

These maps are not intended to represent any form of detailed research and may well include areas listed as unknown. This is a simple exercise as requested through consultative forums by humanitarian practitioners and intended solely as a tool for base decision making.

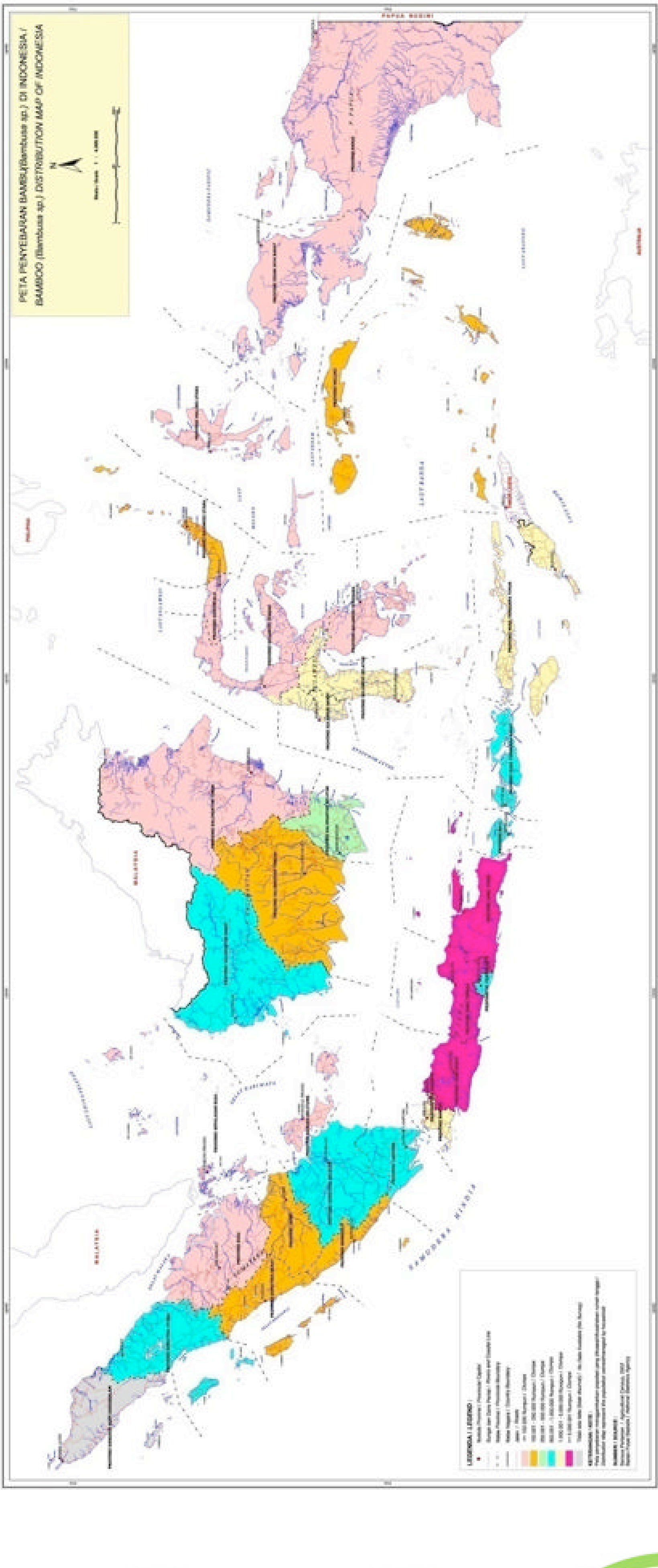
These maps are not intended as a definitive source of information on bamboo availability. Actual availability may vary greatly depending on a number of factors including:

- Changing availability over time (map accurate at 2009)
- Changing patterns of usage and therefore market availability
- Damage to resource by disaster events
- Environmental or political constraints

No map can hope to replace the detailed information that can be gathered through good community consultation.

The following existing map shows a rough approximation of bamboo distribution across Indonesia as reported by the state census.

Map from FAO, Rome (Italy). Forest Products and Economics Div.; International Network for Bamboo and Rattan, Beijing (China). *Indonesia country report on bamboo resources, Jakarta, May 2005.* Rome: FAO, downloaded at ftp://ftp.fao.org/docrep/fao/010/ah778e/ah778e00.pdf.


PETA PENYEBARAN BAMBU (Bambusa sp.) DI INDONESIA /
BAMBOO (Bambusa sp.) DISTRIBUTION MAP OF INDONESIA

LAMPIRAN I. JENIS BAMBU DI INDONESIA

No.	Nama botani	Nama lokal	Daerah ditemukan
1	*Arundinaria japonica* Sieb & Zuc ex Stend.	-	Jawa
2	*Bambusa arundinacea* (Retz.) Wild.	Pring ori	Jawa, Sulawesi
3	*Bambusa atra* Lindl.	Loleba	Maluku
4	*Bambusa balcooa* Roxb.	-	Jawa
5	*Bambusa blumeana* Bl. ex Schul. f.	Bambu duri	Jawa, Sulawesi, Nusa Tenggara
6	*Bambusa glaucescens* (Wild) Sieb ex Munro.	Bambu pagar, cendani	Jawa
7	*Bambusa horsfieldii* Munro.	Bambu embong	Jawa
8	*Bambusa polymorpha* Munro.	-	Jawa
9	*Bambusa tulda* Munro.	-	Jawa
10	*Bambusa vulgaris* Schard.	Awi ampel, haur	Jawa, Sumatera, Kalimantan, Maluku
11	*Dendrocalamus asper*	Bambu petung	Jawa, Bali, Sumatera, Kalimantan, Sulawesi
12	*Dendrocalamus giganteus* Munro.	Bambu sembilang	Jawa
13	*Dendrocalamus strictur* (Roxb) Ness.	Bambu batu	Jawa
14	*Dinochloa scandens* O.K.	Bambu cangkoreh, Kadalan	Jawa
15	*Gigantochloa apus* Kurz.	Bambu apus, tali	Jawa
16	*Gigantochloa atroviolacea*	Bambu hitam, wulung	Jawa
17	*Gigantochloa atter*	Bambu ater, jawa benel, buluh	Jawa
18	*Gigantochloa achmadii* Widjaja.	Buluh apus	Sumatera
19	*Gigantochloa hasskarliana*	Bambu lengka tali	Jawa, Bali, Sumatera
20	*Gigantochloa levis* (Blanco) Merr.	Buluh suluk	Kalimantan
21	*Gigantochloa manggong* Widjaja.	Bambu manggong	Jawa
22	*Gigantochloa nigrocillata* Kurz	Bambu lengka, terung terasi	Jawa
23	*Gigantochloa pruriens*	Buluh rengen	Sumatera
24	*Gigantochloa psedoarundinaceae*	Bambu andong, gambang surat	Jawa
25	*Gigantochloa ridleyi* Holtum.	Tiyang kaas	Bali
26	*Gigantochloa robusta* Kurz.	Bambu mayan, temen serit	Jawa, Bali, Sumatera
27	*Gigantochloa waryi* Gamble	Buluh dabo	Sumatera
28	*Melocanna bacifera* (Roxb) Kurz.	-	Jawa
29	*Nastus elegantissimus* (Hassk) Holt.	Bambu eul-eul	Jawa
30	*Phyllostachys aurea* A&Ch. Riviera	bambu uncea	Jawa
31	*Schizotachyum blunei* Ness.	Bambu wuluh, tamiang	Jawa, Nusa Tenggara Timur, Sumatera, Kalimantan, Sulawesi, Maluku
32	*Schizotachyum brachycladum* Kuez.	Buluh nehe, awi buluh, ute wanat, tomula	Jawa, Sumatera, Sulawesi, Maluku
33	*Schizotachyum candatum* Backer ex Heyne	Buluh bungkok	Sumatera
34	*Schizotachyum lima* (Blanco) Merr.	Bambu toi	Sulawesi, Maluku, Irian Jaya
35	*Schizotachyum longispiculata* Kurz.	Bambu jalur	Jawa, Sumatera, Kalimantan
36	*Schizotachyum zollingeri* Stend.	Bambu jala, cakeutreuk	Jawa, Sumatera