TRAINING MANUAL
TM 05 07/06

Preservation of Bamboo

NATIONAL MISSION ON BAMBOO APPLICATIONS
Technology Information, Forecasting, and Assessment Council (TIFAC)
Department of Science and Technology, Government of India

The National Mission on Bamboo Applications (NMBA) has been established by the Department of Science and Technology (DST), Government of India. Implemented by the Technology Information, Forecasting, and Assessment Council (TIFAC), the Mission is tasked with providing a new impetus and direction to the bamboo sector.
It supports technological upgradation, develops indigenous capacities and enterprise, provides linkages with markets, functions as a platform for exchange of knowledge and technology and encourages association and cooperation amongst sectoral constituents and stakeholders.

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PREFACE

Bamboo culms as well as processed bamboo in the form of cuts, splits, slices and sticks provide excellent raw material for number of value added products and applications in structural and non-structural segments. But bamboo in culm form as well as in processed form faces the problem of biological degradation as a raw material as well as processed products. Though a wide range of protective measures and processes are known to prevent such degradation, their spread is limited due to lack of knowledge and awareness, lack of treatment facilities, and uncertainties about advantages and economics for the same.

This Training Manual elaborates the structure of bamboo culm and limitations it poses to treatability, causes of biological degradation and the factors that hasten or limit the process, traditional as well as chemical preservation techniques and also detail procedures for preparation of bamboo, formulation of chemicals, treatment of bamboo in various forms, and precautions associated with a particular treatment technique. It also includes bill of quantities of chemicals as well as list of manufacturers/ suppliers to enable working out costing and economics of a particular preservation technique. The manual also lists related standards for preservation and treatment of bamboo.

This manual has been written as a joint effort of the NMBA team lead by Ms. Sanghmitra Chakraborty, and Dr.Satish Kumar, former Scientist, Forest Research Institute Dehradun. Lot of inputs has been taken from the earlier work done at the Forest Research Institute, Dehra Dun. The support of Dr.Walter Liese, an eminent authority in bamboo preservation, is gratefully acknowledged for allowing using his pictures related to bamboo protection.

It is hoped that the manual will help understanding the basics of bamboo preservation and encourage use of treated bamboo as well as setting up of treatment facilities at dispersed locations. This will also lead to increased usage of treated bamboo for structural and non-structural products and applications, thereby increasing the shelf life and value of bamboo and bamboo products, as well as reduce frequent replacement of bamboo used in structural applications. Enhanced durability will also enable popularization and increased utilization of next generation bamboo based composites and panels.

(Suneel Pandey)
Mission Coordinator
National Mission on Bamboo Applications
September, 2007

01 Introduction

BAMBOO IS A woody, valuable, strong and exceptionally fast-growing grass. It is commonly and abundantly available throughout the country. It grows easily and in every region except extremely hot and cold deserts.

The most commonly used part of the bamboo plant is the culm. It is typically, but not always, a hollow cylinder that tends to taper towards the top. A culm is segmented into sections (called 'internodes') by nodes. Internodal sections are invariably hollow; nodes are always solid. This structure gives the bamboo culm properties of strength and flexibility.

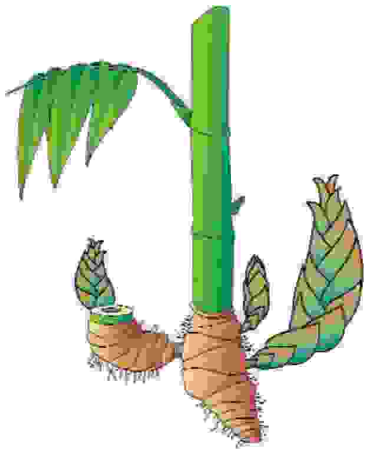
Bamboo culms can be used in their natural or whole form, or cut into sections, or in strips, slivers and slats. Bamboo culms have been used by people and communities for thousands of years, to build houses, fences and bridges. They can be used to make a vast range of utility items, including storage baskets, containers, furniture, agricultural implements and household baskets.

There is also a growing demand for bamboo to meet the needs of new and value-added products and applications, like wood substitutes, panels, flooring, roofing and screens

02 The Bamboo Plant

A BAMBOO PLANT is a complex system. The structural foundation of the plant is an underground vegetative network called rhizome. Over the ground, the most striking feature of the bamboo is the culm or stem. The rhizome and the culm represent the primary vegetative axes. Other vegetative axes are the branches and the root system.

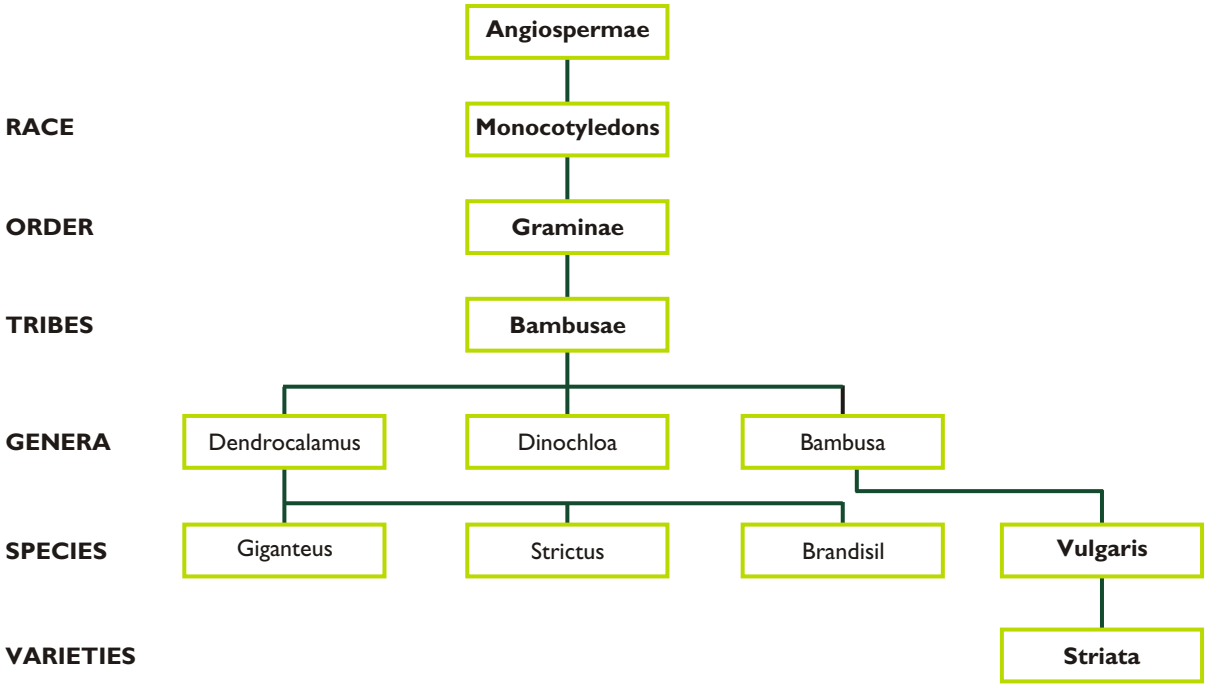
BAMBOO CULM



The diameter, wall thickness, internodal length, node thickness and protrusion vary with the species and the agroclimatic environment in which the bamboo plant grows.

The bamboo culm is a stem thrown up by the bamboo plant. In the growing season, normally during the monsoons, a number of such stems will emerge from the ground in each plant. Most Indian bamboos are clump-forming ('sympodial'), and such stems will tend to be clustered together.

- The culm emerges from the ground initially as a tender shoot. It turns woody rapidly and elongates to its full height within 3-4 months.
- A culm is normally a hollow cylinder. Under arid or otherwise adverse conditions, the culm may tend to become solid or semi-solid, i.e. where its wall thickness and diameter tend to converge.
- Throughout its length, till about three-quarters of the way up, the culm tends to have almost the same diameter; at best, there is a marginal narrowing. Towards the tip, it tends to taper more rapidly.
- Branches and branchlets spread from the nodes of the culm and these bear leaves.
- The culm may be thought of as a jointed pipe. It consists of hollow sections (internodes) segmented by solid nodes.



Internodes

Hollow sections of the culm are called internodes. In these sections, the culm wall surrounds a large cavity called the lacuna or pith.

- The outer part of the culm wall is called the cortex. It consists of epidermis cells covered with a cutinized waxy layer. This layer protects the culm against physical damage. It also acts as a watertight barrier, preventing loss of moisture.
- The innermost part of the culm wall is called the pith ring. It consists of layers of parenchyma cells which are often heavily thickened and lignified.
- The ground tissues of the culm wall consist of parenchyma cells. These cells are axially oriented. Their large volume provide for storage of nutrients, mainly starch and carbohydrates. These cells are connected with each other by small pits, located mainly on their tangential walls. These pits also promote the radial diffusion of a preservative solution.
- Ground tissues of the culm wall, which consist of parenchyma cells, are also embedded with vascular bundles, which are composed of conducting vessels (metaxylem vessels, sieve tubes with companion cells) and fibres. A typical culm wall structure consists of parenchyma cells (52%), conducting vessels (8%) and fibres (40%).
- The embedding of vascular bundles in ground tissues contributes to the elasticity of the culm as a reinforced matrix. And the presence of fibres gives tensile strength to the culm, and enhances its physical and mechanical properties.

- Across the culm wall, the vascular bundles become smaller and denser from the inner side towards the cortex, as well as along the height of the culm. Accordingly, the percentage of fibre in the culm wall increases from the inside of the culm wall to the outside, and from the bottom to the top. Consequently, specific gravity and strength properties of bamboo increase from the inside of the culm wall to the outside, and from the bottom to the top.

- It is also seen that conducting vessels increase slightly from the outer part of the culm wall to the inner part, with the maximum vessel area in the middle third of the culm wall.

- The conducting vessels act like water pipes for transporting water and nutrients from the roots via the rhizome and culm into the leaves for transpiration and assimilation. These also function as pathways for the preservative solution.

Nodes

The hollow sections, or internodes, of the bamboo culm are segmented by nodes, which are solid, and where cell elements of the culm get converged with their axial orientation changing to the transverse or across-the-culm direction.

- Fibres of the bamboo become shorter at the nodes; also, their orientation changes from axial to transverse direction. This results in higher specific gravity, lower volume shrinkage and lower tensile strength compared to the internodes.

- Along with the cell elements, conducting vessels at the nodes also converge and provide transverse interconnections for movement of water, nutrients and preservative solution through interconnected conducting vessels

03 Treatability of Bamboo

THE STRUCTURE OF the bamboo culm and of its component elements has a strong bearing on techniques and methodologies of treating bamboo, and on their relative efficacy.

The efficiency of chemical treatment of bamboo to enhance its service life is influenced by the following anatomical structure of the bamboo culm.

- There are no radial pathways in the culm tissues, like the ray cells in wood, and lateral cell-to-cell movement of preservative depends on a slow diffusion process.
- The extent of conducting tissues are only 8% of the culm tissues, in comparison to 70% for softwoods, 20-30% for hardwoods and 20-30% for rattan, making treatment of bamboo a difficult and time-consuming process.
- The radial penetration of the preservative through the outer culm wall is resisted by the presence of the cortex. Also, the diffusion of preservative from the hollow inner cavity is hindered by the heavily thickened and lignified tissues.
- Though the axial orientation of the vessels make the flow of preservative easy along the internodes, their isolation from each other by parenchyma makes movement of preservative solution difficult in the transverse direction.
- Within the culm wall, the diffusion rate is higher in the radial direction than in the tangential direction, due to greater structural homogeneity of vascular bundles in the radial direction.
- As soon as the culm is harvested, wound reaction blocks the conducting vessels - this limits the access of preservative. Bamboo

Freshly cut culms are easier to treat due to the water-filled cells providing a continuous transportation channel.

culms thus should be treated immediately after harvesting. Also, both ends of the culm should be cut up to the next node in order to remove the blockage of vessels that might have already occurred after culm felling.

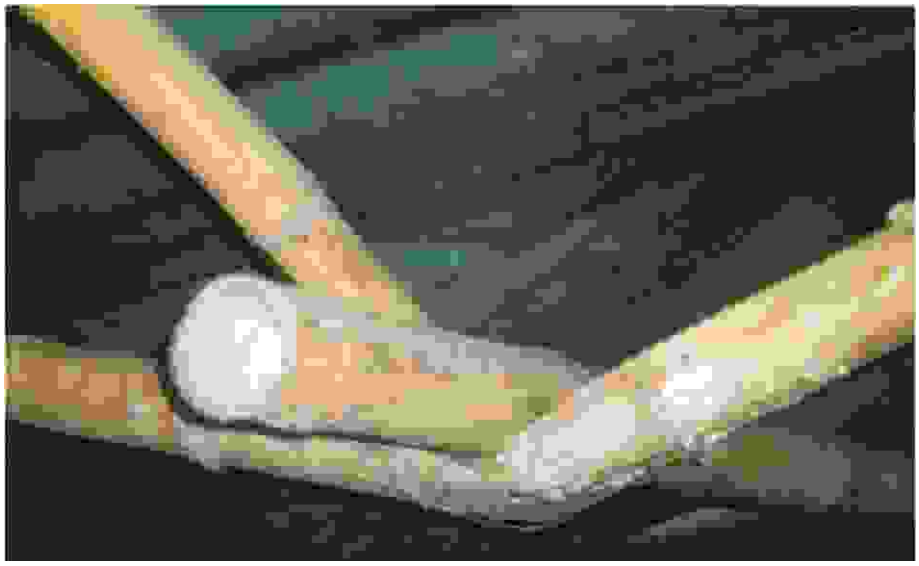
- The distorted axial orientation of the nodes hinders penetration, especially while soaking dry culms - the drying of the cell sap prevents cell-to-cell diffusion

04 Why is Treatment Necessary for Bamboo?

BAMBOO IS A natural material of organic origin. Without any protective treatment its durability is less than five years. Unlike varieties of timber like teak, bamboo structure is void of toxic deposits. The presence of starch makes it more attractive to micro-organisms. Biological degradation can affect the usage, strength, utility and value of the bamboo/bamboo product leading to:

- decay and disintegration
- splits or cracks
- unsightly stains and blotches

Treatment is absolutely necessary when bamboo is used as a structural member where safety is of major concern. Also, frequent replacement would be time-consuming and involve costly labour. Increasing life by



treatment is more economical in the long run.

What is Treatment?

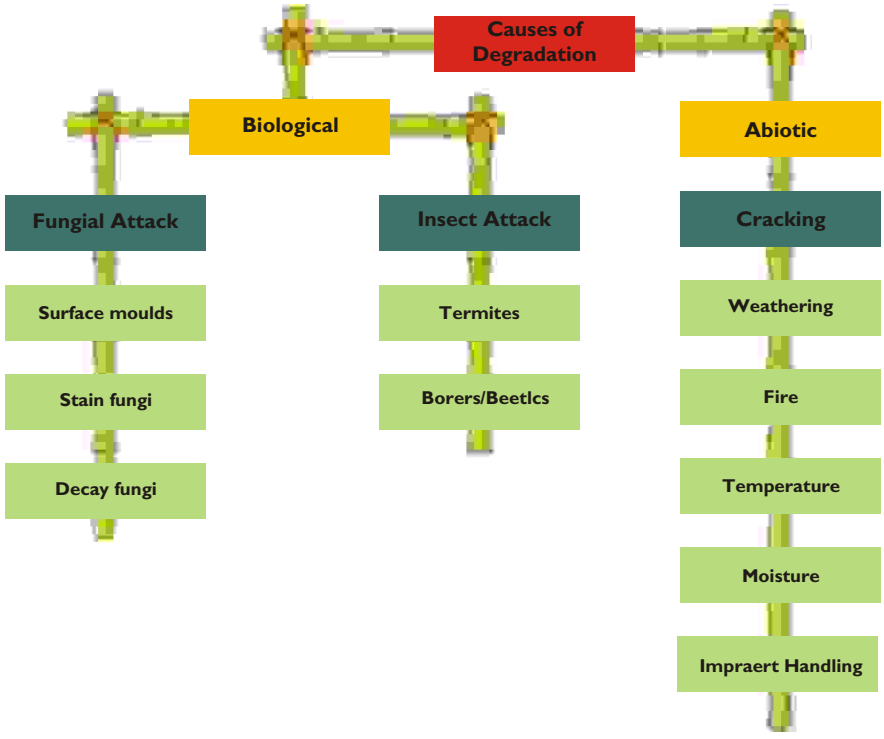
In order to improve the durability and performance, bamboo and bamboo products are treated with or without the use of chemicals.

Treatment is intended to:

- Extend durability and prolong useful life.
- Arrest and delay degradation.
- Preserve dimensional stability and retain strength.
- Impart properties like fire resistance, lustre, etc.
- Improve aesthetic qualities

05 Causes of Degradation

AGENTS CAUSING DEGRADATION in bamboo/bamboo products can be of either biotic or abiotic origin. Biotic agents are commonly insects and fungi. They attack due to the presence of starch and other carbohydrates, obtaining their supply of food from the bamboo and degrading it. Abiotic factors are cracks/splits, weathering and fire.



Biotic agents are living organisms like fungi and insects, which derive food from the bamboo culm for survival and growth.

Fungi

They originate from very fine, air-borne spores present in fruit bodies, and occur everywhere. They nourish on the nutrients in the bamboo culm.

Damage becomes noticeable at an advanced stage, when substantial fungal growth is already underway. Fruit bodies appear subsequently on the outside surface and their removal does not stop the decay process inside the culm wall.

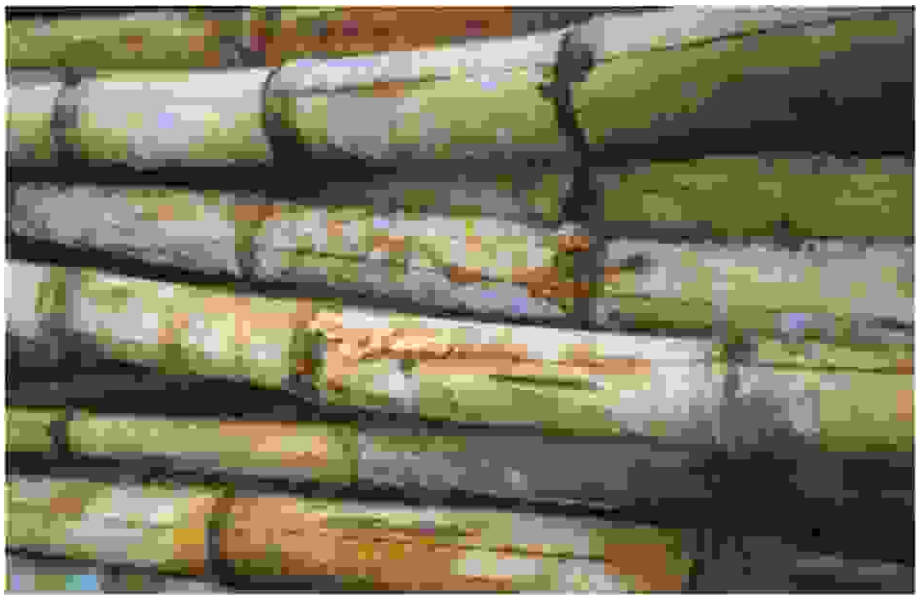
Depending upon the moisture conditions, three types of fungi occur: *surface moulds, stain fungi and decay fungi.*

Surface Moulds

These grow on the surface and at the cross-ends of green culms, in storage stacks of green and split bamboo where the inner part is exposed and on finished products.

They require a humid and stagnant atmosphere for growth.

They do not influence the strength of the bamboo but reduce its aesthetic appearance producing shallow blemishes which can be wiped off.



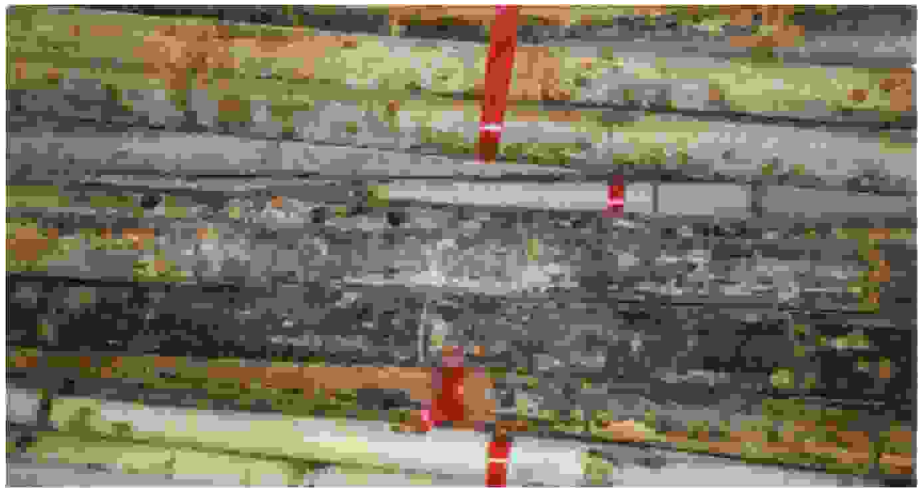
Stain Fungi

They can penetrate round bamboos from cross cut ends as well as from cuts in the nodes after removal of the branches. They nourish on the starch and carbohydrates. Stain fungi affect mostly split bamboo and slivers.

They require high moisture for survival and growth

Attack is indicated by shades of blue/greyish-black discolouration on the surface in the form of spots and streaks. It reduces the aesthetic

appearance but does not affect the strength properties of bamboo except in severe cases of attack. Fruit bodies are produced on the culm surface, whereby the hyphae may rupture its hard skin by forming blisters beneath the epidermis to release spore masses.

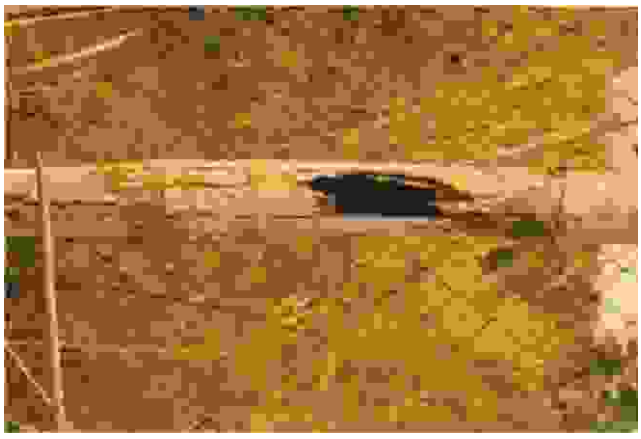


Decay Fungi

These fungi cause the most serious kind of damage and grow within the lumen of the cells. The enzymes either decompose only the cellulose and hemicellulose leaving behind the lignin leading to brown rot, or they decompose lignin leading to white rot. White rot is more common in bamboo than brown rot.

Early decay is difficult to detect. Even before slight colour change or weight loss becomes apparent, the strength properties are much reduced, in particular the impact-bending strength. Early damage can be characterised by dampness in bamboo. At later stages of deterioration the culm is soft to the touch and may be only a fibrous or powdery mass.

Advanced brown rot leaves a brownish mass, while white rot leaves white streaks on the culm's surface.



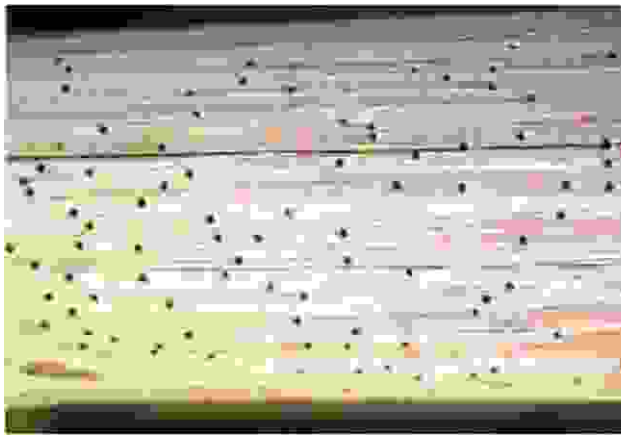
Insects

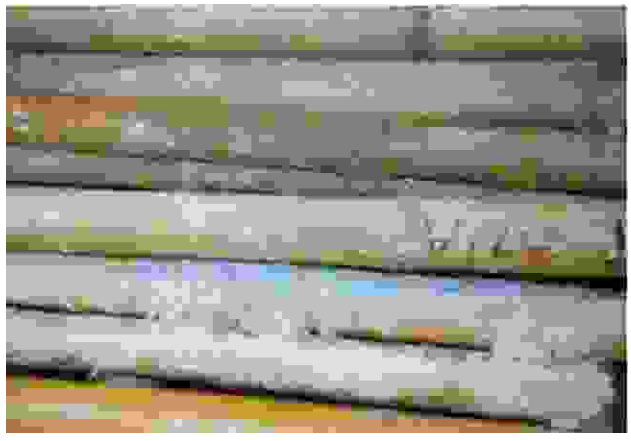
Beetles and termites are the most commonly occurring insects in bamboo. They do not require any specific conditions. Warm and moist climate conditions favour insect attack.

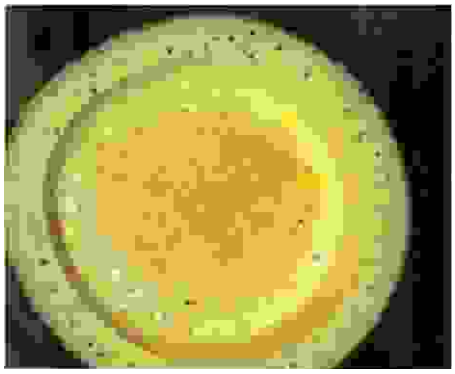
The life cycle of an insect is divided into four stages: egg, larva (caterpillar), pupa and adult. Eggs hatch into minute larvae, which penetrate by gnawing through the tissue by mechanical and chemical action. The particles are digested in the gut of the larvae and the frass is pushed out as pellets at the rear end. The larva pupates and finally the adult beetle chews its way out of the bamboo culm leaving exit holes on the surface. The adult may again lay eggs before dying resulting in multiple attack of the same stock or culms freshly added.

Commonly known as powder-post beetles, these may consume the whole bamboo culm leaving only a thin outer shell on exiting.

Larvae of beetles nourish on the starch and sugars in the parenchyma cells in the culm and the intensity of attack will depend on the amount of starch available. Thus culms with higher starch content, for example, those harvested during shooting or the rainy season, are more prone to attack. Once the larvae grow, they can consume other cell wall components as well.







Powdery dust falling out of holes indicates an ongoing attack. They can tunnel through the entire inner tissue leaving behind only a thin surface of the hard cortex which may give a false impression when evaluating the significance of damage for repair work.

Termites

These insects live in well-organized colonies having a population of several thousands to a few millions of individuals. They are among the few insects capable of using cellulose as a source of food.

Some varieties of termite (subterranean) need high humidity for survival and access to water. Other types (dry-wood type) survive without ground contact, obtaining moisture from the culm.

Subterranean termites attack bamboo on ground contact by extending above the ground in tube-like runways made of soil and faeces. The gnawing takes place inside the bamboo culm.

Dry-wood termites build their nests inside the bamboo culm parts that they are eating. Often attack becomes visible only at a late stage of deterioration.

FACTORS AIDING BIOLOGICAL DEGRADATION

Food material and absence of any toxic substance in the food source: The presence of starch makes bamboo attractive to blue stain fungi as well as borers.

Oxygen: Decay fungi need oxygen for respiration. Limiting the supply of oxygen retards fungal growth. Some fungi, however, can exist even at low oxygen levels associated with high moisture levels.

Moisture content: Fungi thrive in humid environments. A moisture level of 40 to 80% is ideal for rapid growth. Dry bamboo with moisture below 20% does not promote fungal growth.

Temperature: Between 25^{0}C to 35^{0}C is ideal for fungal growth.

Factors like cracks/splits, weathering and fire are abiotic agents which cause degradation in bamboo.

Cracks and Splits

These occur due to stresses caused by sudden drying and direct exposure to sun. Cracks do not really weaken the culm but create points of entry for decay organisms. Splitting of bamboo arises due to nailing without pre-boring, especially in thin-walled bamboo. End splitting can be prevented by coating ends with wax emulsion or coal tar.

Weathering

Weathering of exposed bamboo occurs due to the interaction of different atmospheric conditions, such as fluctuations of temperature and relative humidity. Repeated drying and wetting of exposed bamboo results in widening of minute cracks produced on the surface. Solar radiations cause degradation of cellulose. The wind and dust particles have sand blasting effect on the culm surface giving a weathered look.

Fire

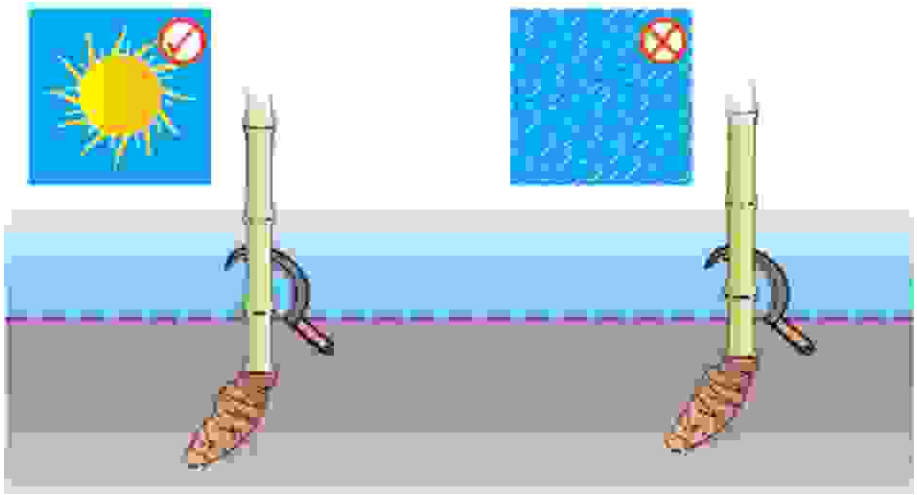
Bamboo is combustible and fire poses a great danger. Though the fire resistance of bamboo is similar to timber, treatment to improve fire retardance is ineffective and expensive

06 Good Harvesting Practices

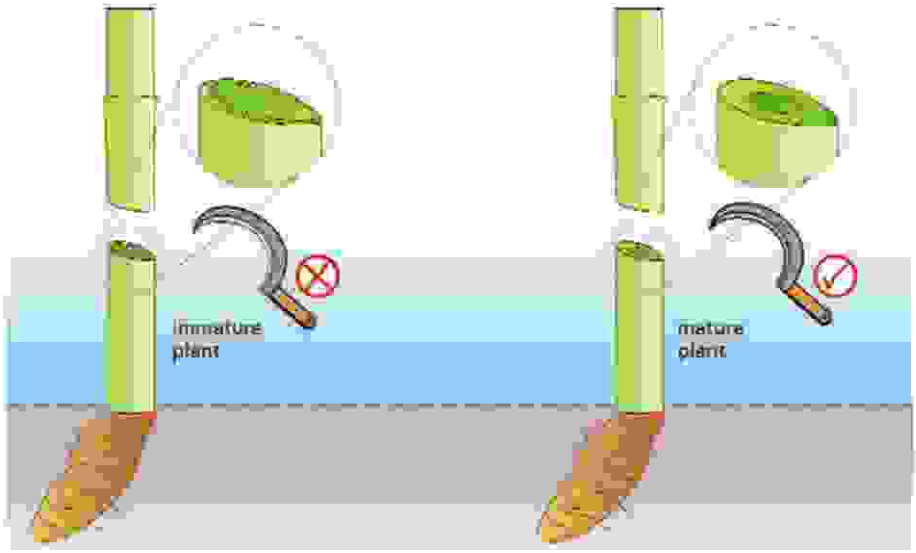
GOOD HARVESTING PRACTICES will enhance the resistance of bamboo culms to degrading factors and retain their shape, form and strength.

DO FELL

- *During the dry season:* Winter is the period of dormancy of the bamboo plant. During this period, the plant is acquiring and conserving nutrients for the next season of growth; starch content is lower; and the chances of borer attack, now and later, is lower. The moisture content of bamboo culms is lower and relatively stable as well, reducing the possibility of subsequent splitting and cracking.

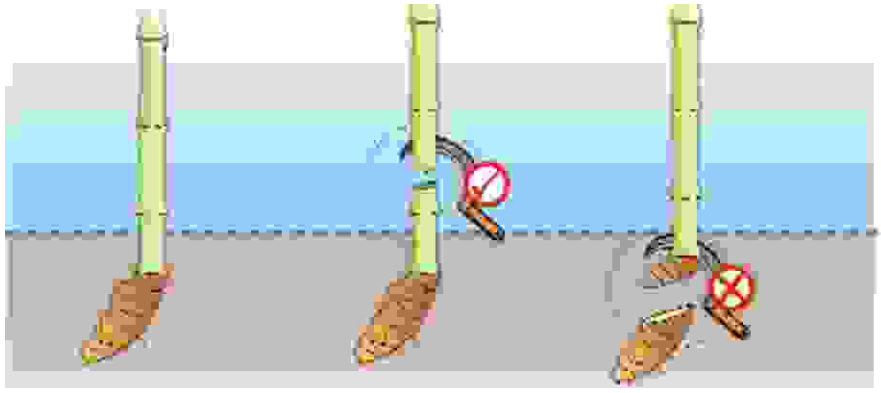


- *Only mature bamboo:* Immature bamboo culms (< 3 years old) tend to have higher starch content. In addition, the process of lignification is not complete, and they will be less strong and usually collapse on drying



- Only healthy and selected culms: Good products cannot be made from diseased and rotten culms.
- At the right height: Fell culms 10-15 cm from the ground and just above the node. In this way, aceptacle in which rainwater can collect will not form; this can weaken the plant system.

At or near the harvest site, keep the culms stacked vertically in a sunny place. with the foliage (leaves, branches) intact. Kept in this way for 3-4 days after felling, the starch content in the culms will be lowered



AVOID

- Felling in the growth season: In this period, normally coinciding with the monsoon, starch content and moisture is higher. Also, new shoots emerge at this time, and felling operations can damage or destroy shoots.

DO NOT

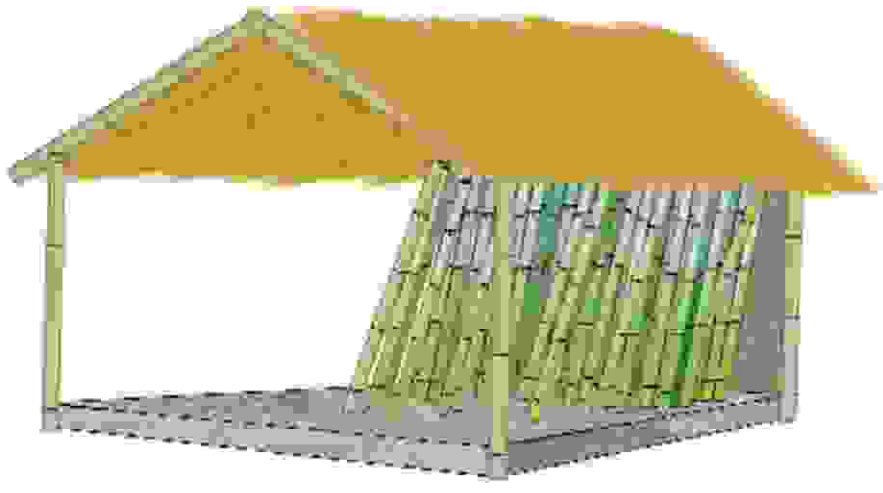
- Damage or expose the rhizome while harvesting: This can cause serious damage to the bamboo clump, and affect its future health.
- Throw culms on to hard ground: Such stress can induce cracks along the length of the culm.
- Drag the culms along the ground: This may cause stains and blemishes

07 Post-Harvest Practices: Storage

- Keep bamboo culms away from direct contact with soil to prevent fungal and termite attack - place on tarpaulin sheet or thick plastic sheet, or raised on a PCC platform.
- Protect from rapid changes in moisture - store in a pond, tank or river (this will also help to leach the starch out), or cover the culms with a thin canvas sheet.
- Provide good ventilation.
- Remove infected culms from storage area.

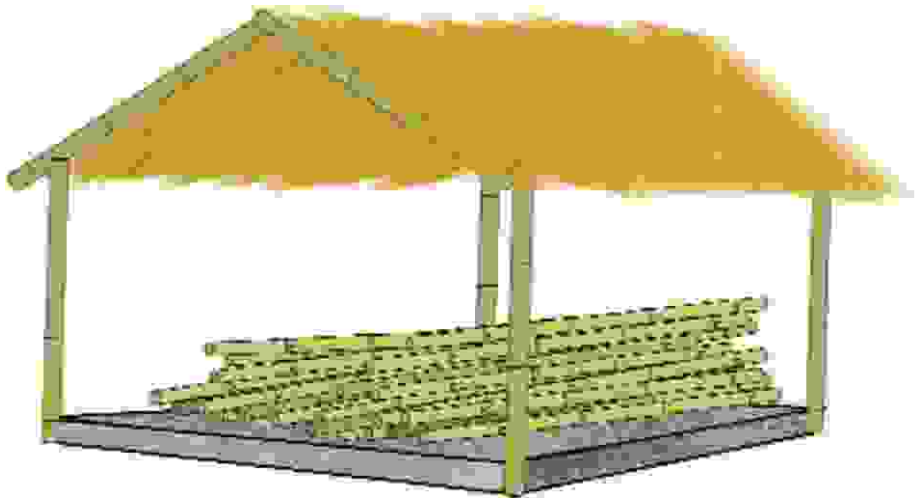
Stacking of Bamboo

Vertical stacking - recommended for applications other than pulping. Vertical stacking gives quick drying and less chances of fungal attack. Culms can be stored in an upright position against the wall.



Horizontal stacking - generally preferred for large stacks. Stacking should be done on raised platforms without ground contact, and allowed to dry uniformly.

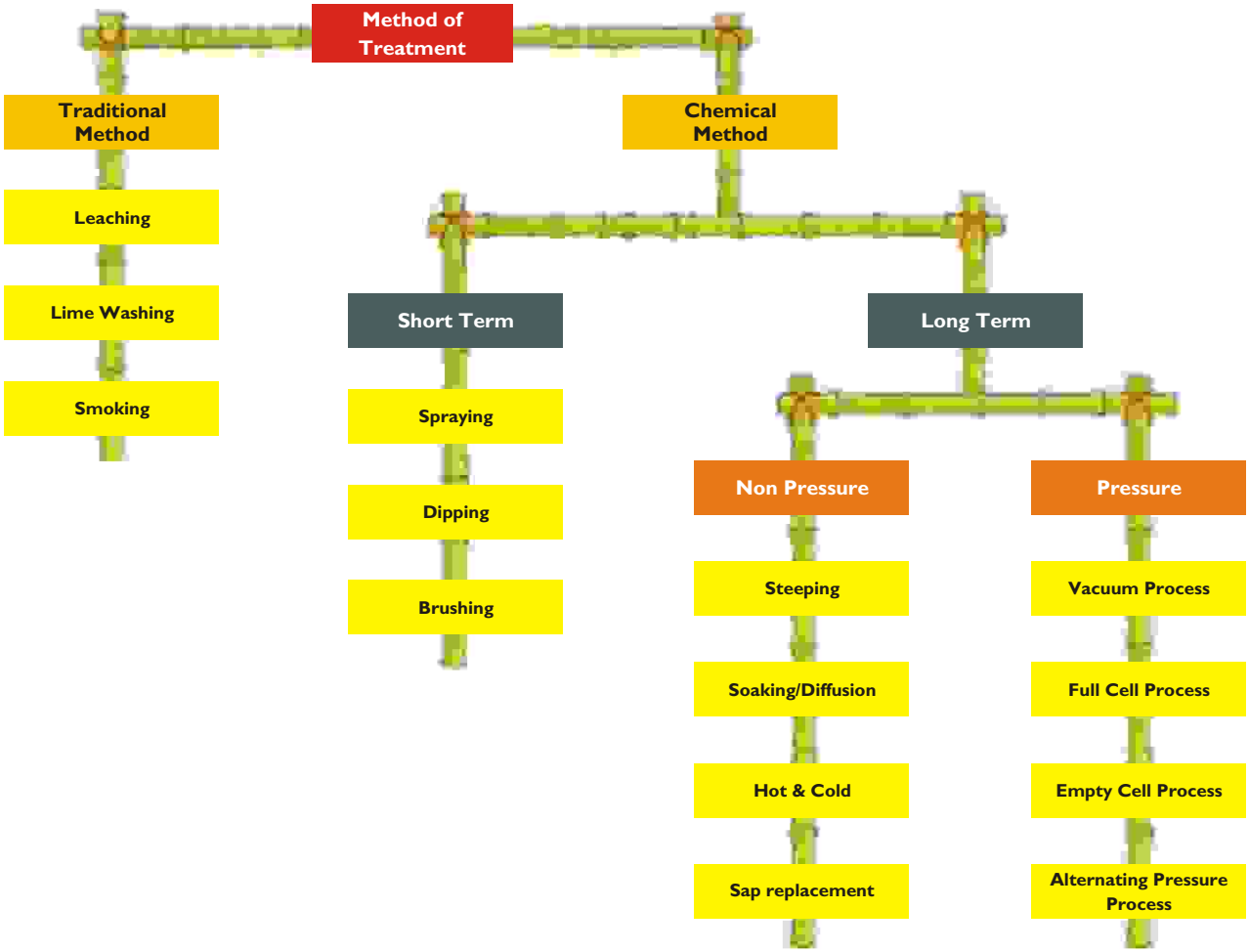
The culms at the bottom of the stack may crack/bend due to the weight of the stack.



Storage in Water: water storage is best suited for bamboo to be processed green. Storage in water causes leaching of starch and maintains pliability. In case the bamboo is stored for long periods, needs to be transported over a distance or the ambient conditions are highly favourable for fungal/insect attack, prophylactic treatment should be given. It should be mentioned here that if fungal attack sets in, the effects of the attack - like fungal stains - cannot be removed completely even after subsequent treatment. Also, the fungal spores may remain within the bamboo and multiply later

08 Methods of Treatment

TREATMENT METHODS CAN be divided into traditional/time-tested methods and chemical methods.



Selection of the treatment method depends on many factors:

- State of bamboo - green or dry
- Form - round bamboo, splits or bamboo products.
- End applications - in ground contact, exposed to atmosphere, undercover, structural/non-structural.
- Scale - quantity to be treated and time available.
- Potential causes of decay - biotic (fungus/insects) and abiotic (cracks/weathering).

TRADITIONAL TREATMENT METHODS

These are age-old methods which have been practiced in areas where bamboo commonly grows. They are simple and cost-effective without the use of supporting equipment. But these methods are not appropriate for long-term protection of bamboo.

CHEMICAL TREATMENT METHODS

In these treatment methods chemical preservatives are used to protect the material from degradation. These are well established methods providing desired protection even in adverse conditions

09 Traditional Treatment

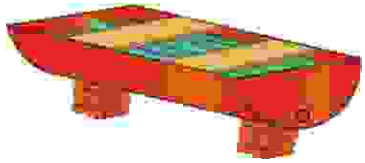
LEACHING, SMOKING and lime washing are age-old treatment methods which have been practised where bamboo is grown and used.Sometimes, for craft items, protection is also given by use of natural dyes and lacquers, which also lead to value addition.

LEACHING

Leaching helps remove starch and also enhances permeability for future treatment by diffusion and pressure. Mechanical properties are affected for upto 2- 3 months of water storage.

This method is appropriate for treating any quantity of bamboo. It is also recommended for craft and mat applications where pliability is required.

Method:



Bundle culms/splits and store in running water or tanks.

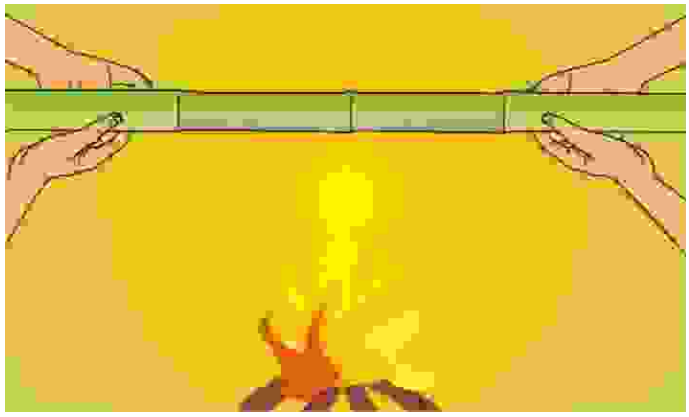
Use sinker loads for complete immersion.

In the case of tanks, change the water weekly to prevent growth of bacteria which will cause staining and bad odour.

For round bamboo, nodes should be punctured if possible before leaching.

SMOKING

Traditionally, culms are stored over the hearth or fireplace. The moisture content in smoked culms is thus reduced so that biological degradation cannot take place. Built-up deposits from smoke form a protective layer on the culm. Smoke drying also reduces splitting.

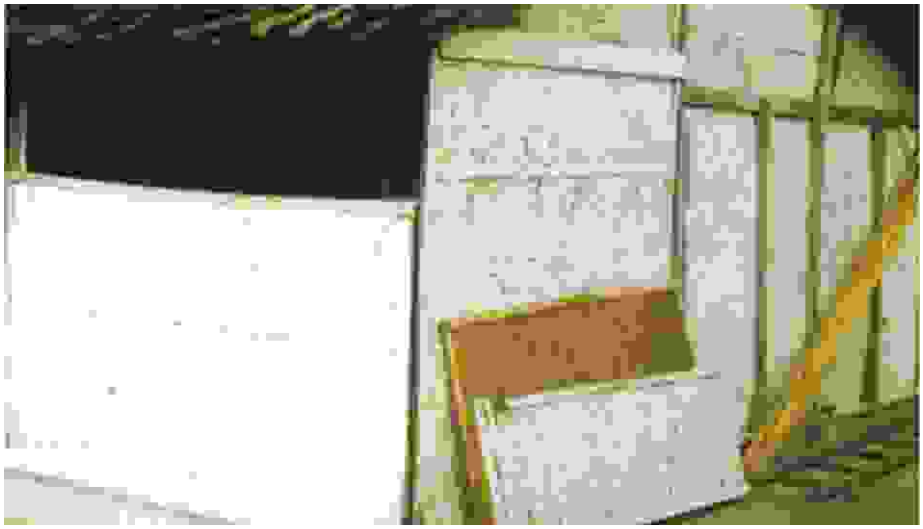


LIME WASHING

Lime or whitewashing is mainly used for ornamental effect. Culms and mats are painted with slaked lime($Ca(OH)_2$) which is then transformed into calcium carbonate, $CaCO_3$, which inhibits water absorption and delays fungal attack. Bamboo mats can also be tarred, sprinkled with sand and whitewashed after drying.

BAKING

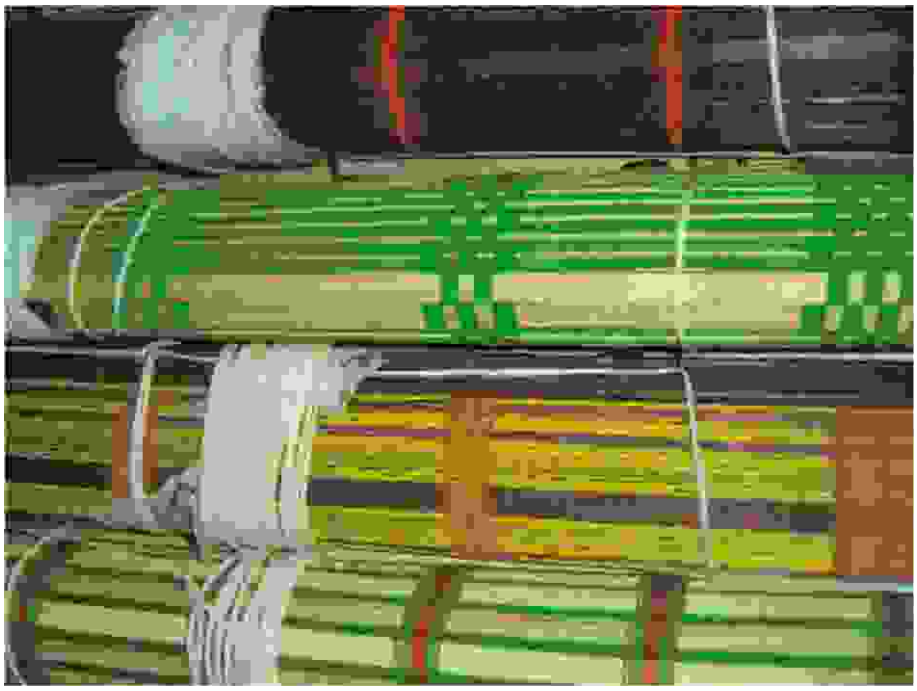
Baking on open fire has been used to straighten crooked bamboo culms. Bamboo is rotated on an open flame to prevent localised heating. The high temperatures destroy the starch and other sugars and also produce tar in the structure. It kills existing infestations if any. Stresses produced during heating gives dimensional stability to the culm. A lower equilibrium moisture content regime prevents any subsequent fungal attack if bamboo is used in interior application.



NATURAL DYES, VARNISHES AND PAINTS

Natural dyes have been used for ages to provide protection and colour to bamboo products. Dyes are applied by boiling the material with the colouring agent, during which the starch is also leached out.

Paints and varnishes are applied on to the bamboo surface to protect it from dirt and moisture, and to provide ornamental effects. They form a film on the surface of the bamboo. Blistering of the paint/varnish leaves the bamboo surface exposed, and fungal and insect attack may follow. It is therefore recommended to provide a protective coating of preservative before application of paints and varnishes

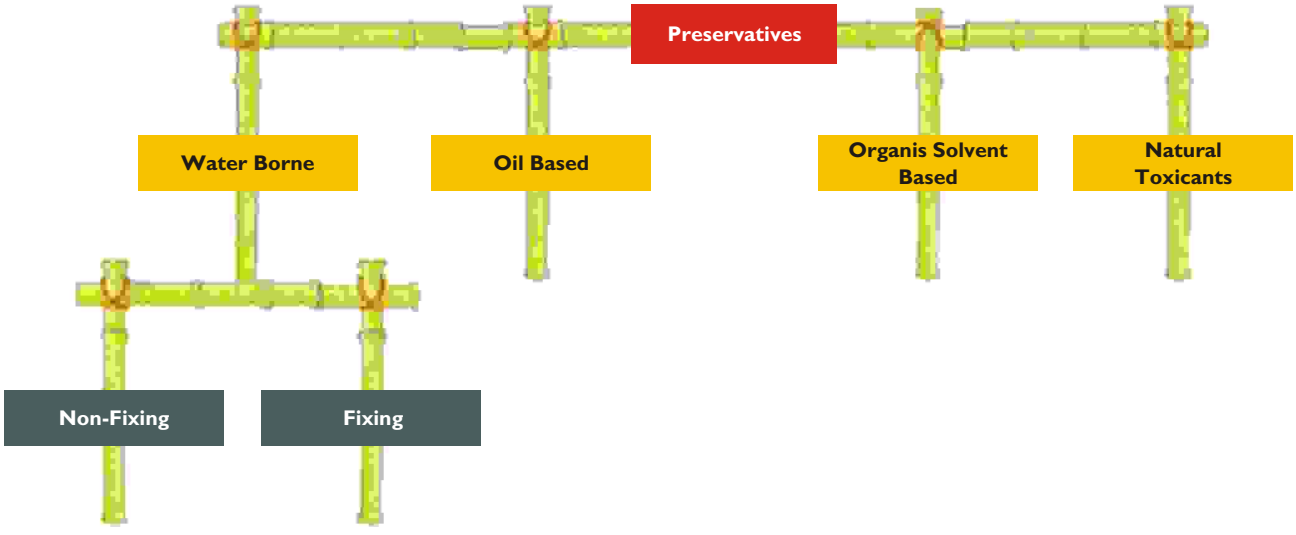


10 Chemical Preservation

USE OF CHEMICAL preservatives with or without the help of special equipment ensures long-term protection. Depending upon the method of treatment, chemicals can. impart shortterm or long-term protection.

WHAT ARE CHEMICAL PRESERVATIVES?

These are formulations of single compounds or mixtures which protect wood/bamboo against biological degradation and discolouration caused by biological attacks. With a few exceptions, chemical preservatives are toxic. Selection and application has to be done with care to meet performance and environment requirements. Depending upon the carrier solvents, preservatives are divided into different categories.



Water-Borne Types

Water-soluble salts are dissolved in water. On treatment, the water evaporates leaving the salts inside the bamboo. These are further categorized into non-fixing and fixing types.

Non-Fixing type preservatives

These are leachable solutions and their use is restricted to bamboo used in dry conditions and under cover. Bamboo treated with these preservatives should not be exposed to rain or ground contact. Common example: Boric acid: Borax & copper sulphate

Fixing Type preservatives

These formulations are proportionate mixtures of different salts which interact with each other in the presence of bamboo/wood and become chemically fixed. In principle, the degree of fixation and efficacy depends upon the nature of the components and their combination. For example, Chromium is responsible for fixation, copper is effective against decay fungi and soft rot and the third compound acts against insect and fungus. The process of fixation requires some weeks during which the material should be stored under cover. Slow fixation is preferred in case of bamboo as it allows diffusion and better distribution of preserving salts.

Common example: Copper-Chrome-Boron, Arsenic Pentoxide & Boric Acid

Oily Preservatives: Creosote

Coal tar and creosote available from coal is a dark brown viscous liquid. Creosote should be used exclusively for pressure processes or hot and cold treatment. Being oily, it imparts water repellence to the treated material. It is effective against fungal and insect attack. Due to its dark brown colour and bad odour, its use is restricted to exterior applications, especially in contact with mud/ ground

Light Organic Solvent-based Preservatives (LOSP)

These are slightly more expensive preservatives where the organic solvent acts as a carrier for toxic molecules and later evaporates, leaving the active ingredients behind. They are available commercially in ready-to-use forms. A good formulation is an appropriate mixture of fungicides and insecticides. There is little change of colour of the treated material but a residual odour may remain for some time. The method of use will be recommended by the manufacturer. Formulations available in concentrates are more economical to use.

Common examples: Trichlorophenol (TCP) and Copper/Zinc napthenates (metallic soaps) are used as fungicides. Lindane/ cypermethrin is used as an insecticide.

Natural Toxicants

Some naturally occurring materials can prevent decay to some extent. Long-term protection is not possible through these preservatives. The Giant Indian Milkweed is deadly to beetles and fungi. Boiling of slivers

with fresh leaves and stem of this plant for 30-60 minutes will prevent attack.

COMMON CHEMICAL PRESERVATIVES

Boron containing compounds: water-borne non-fixing type**:** These are usually a mixture of boric acid:borax. Readymade formulation (disodium octaborate 1:1.4) is also available. Boron salts are effective against borers, termites and fungi (except soft rot fungi). High concentration salts have fire-retardant properties. They are not toxic and can be used for treating bamboo products like baskets, dry containers, etc. which come in contact with food products.

Zinc Chloride/Copper Sulphate: water-borne non-fixing type: These are single salts and offer limited protection. They are highly acidic and can cause corrosion of metal fittings. Zinc Chloride is highly hygroscopic and treated bamboo will give a wet look in rainy season. This can adversely help paints and other finishes.

Sodium Penta Chloro Phenate (NaPCP): water-borne non-fixing type**:** It is basically a fungicide. It is also applied with boric borax for protection during shipment and storage of green bamboo. But due to its toxic nature it has been banned in several countries. It is the most effective chemical to prevent moulds and blue stain fungi.

Copper Chrome Arsenic (CCA): water-borne fixing type**:** It is a heavy duty broad spectrum preservative patented as AsCu; the formulation consists of arsenic pentoxide and copper sulphate with sodium dichromate as the fixative in the ratio 1:3:4. CCA has been found to provide protection for 50 years or more. Due to the arsenic component only exterior applications are recommended. Though no study has revealed adverse effects due to exposure to treated products, it must nevertheless be handled with special care.

Copper Chrome Boron (CCB): water-borne fixing type**:** It is a broad spectrum preservative containing boric acid, copper sulphate and sodium dichromate in the ratio 1.5:3:4. It is a good alternative to CCA but less effective with a lower degree of fixation, of the Boron component.

Thio - cyanomethyl - thio - benzothiazole (TCMTB) along with Methylene - bis - thiocyanate (MBT):

It has been promoted as a substitute to NaPCP for prophylactic treatment of green bamboo. The formulation is expensive and has to be used with great care as it is injurious to eyes.

Ammoniacal Copper Arsenate (ACA): water-borne fixing type**:** The formulation consists of copper sulphate and arsenic trioxide dissolved in ammonia. It gives high degree of protection and better penetration due to the presence of ammonia, which swells in the bamboo structure

Creosotes: oil type
It is a broad spectrum preservative and is a cost effective chemical for treatment for exterior applications. It has been used for treating railway sleepers and wooden poles.

Trichlorophenol (TCP): LOSP**:**
It is a more eco friendly substitute for Pentachlorophenol. Ready to use (5%) solution of this fungicide along with insecticides for broad spectrum performance are commercially available. Concentrates which can be diluted with mineral turpentine oil are more economical for industrial use.

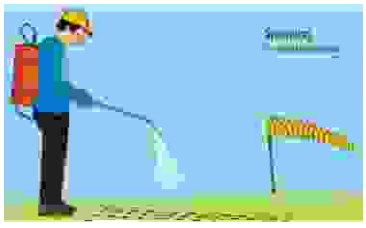
Copper/Zinc soaps: light organic solvent-based (LOSP):
They have emerged as alternatives to other organic preservatives which cause environmental hazards. Napthenates of copper and zinc are most common. They are available as ready-to-use formulations containing appropriate amounts of insecticides. They are slightly more expensive than TCP formulations. However, they are more eco-friendly and also have no pungent smell

11 Short-term Chemical Protection

THE METHOD OF chemical treatment used depends upon whether intermediate protection is required (raw material stock) or the material has to be protected over an extended period (finished product).

METHODS FOR SHORT-TERM PROTECTION

Prophylactic treatment is done to prevent immediate attack when the bamboo is stored for a few days or during transportation, using mild doses of chemicals. Such treatment is also done to intermediate products like slats, slivers and mats which are to be used in the manufacture of composite products. Treatment methods like spraying, brushing and dipping give superficial protection, effective for a short period only.



Spraying

This method is suitable only for large stacks of bamboo stored under cover in depots.

1 Stack bamboo horizontally on a raised platform and preferably sloping ground, and on a polythene sheet.

2 For large stacks, use an industrial sprayer. For small stacks, a backpack is sufficient.

3 Spray chemicals on the top taking special care to cover the ends and the cut surfaces (2% solution of boric acid:borax. Mix 1 kg of Boric acid, 1 kg of Borax in 100 litres of water).

4 Collect the drained solution for reuse

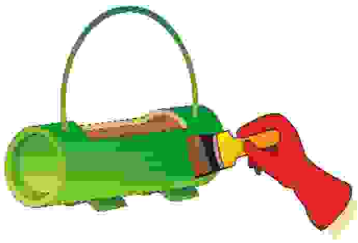
Points to Remember
Always use protection during spraying - masks, gloves, goggles, etc.

Spraying causes environmental pollution - only non-toxic chemicals like boric acid: borax should be used.

Always collect and reuse drained chemicals.

Spray in the wind direction.

Brushing

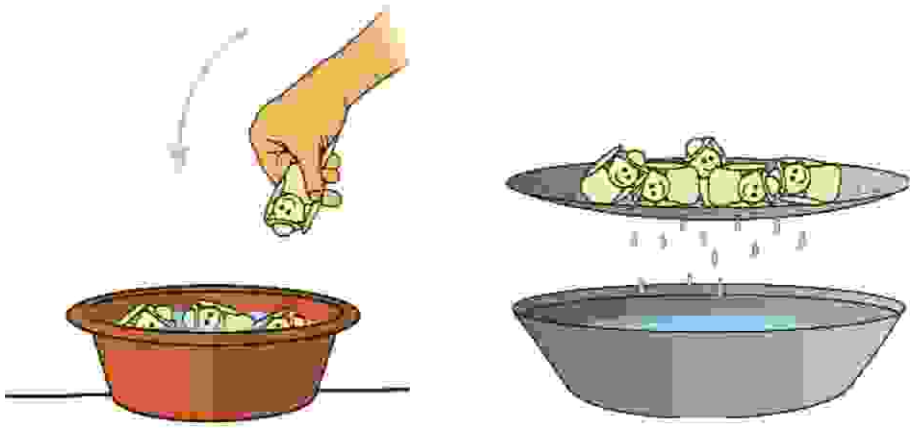


It is suitable for small handicraft and household items. 2-3 coats of chemicals should be given using a brush. The size of the brush will depend on the material surface to be covered.

Dipping

Dipping is used for medium quantities of bamboo/bamboo products. Dipping is more effective than spraying or brushing.

A momentary dip of 30 seconds to a minute is sufficient to protect the material. The excess material should be drained and reused.



CHEMICALS FOR SHORT-TERM PROTECTION

2% Boric acid and Borax (50:50) solution (mix 1 kg of Boric acid and 1 kg Borax in 100 litres of water) for protection against fungal attack.

2.1 % solution of TCTMB:Boric acid:Borax (0.1:1:1) for total protection against stain fungi, decay fungi, borers and termites, where use of Sodium pentachlorophenate is not permissible. (Mix 100 g TCMTB, 1 kg Boric acid, 1 kg Borax in 100 litres of water.)

1% (active ingredients) emulsion of Lindane (dilute 1 litre of 20EC Lindane formulation available in the market to 20 litres of water) for protection against insect attack

12 Long-Term Chemical Protection

WHEN THE MATERIAL is to be stored for long periods, the preservative needs to penetrate sufficiently to provide protection over the extended period. The same preservative can give short-term or long-term protection depending upon the method of treatment. Long-term protection can be given with or without the use of pressure. The method is determined by the moisture content in bamboo, type of preservative and end-use.

NON-PRESSURE TREATMENT

The methods for non-pressure treatment of bamboo are butt end treatment, soaking, hot and cold treatment, and sap replacement. Methods like butt end treatment and diffusion are suitable for green bamboo only. Hot and cold treatment requires air-dry bamboo.

Butt End Treatment

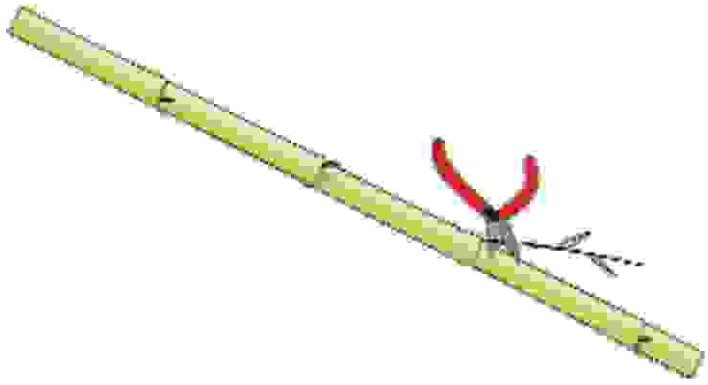
In this method, green culms are placed vertically in the preservative. The solution penetrates the vessels by capillary action and subsequently by diffusion. The time for treatment will depend upon the moisture content and length of the culm.

Scale: Medium-scale operation for both round bamboo and splits.

Method

1 Prepare solution of water-borne preservatives like Boric acid:Borax 1:1.4 (or CCB) in a container or cement tank.

2 Cut bamboo sections of maximum 2 m length and remove foliage.



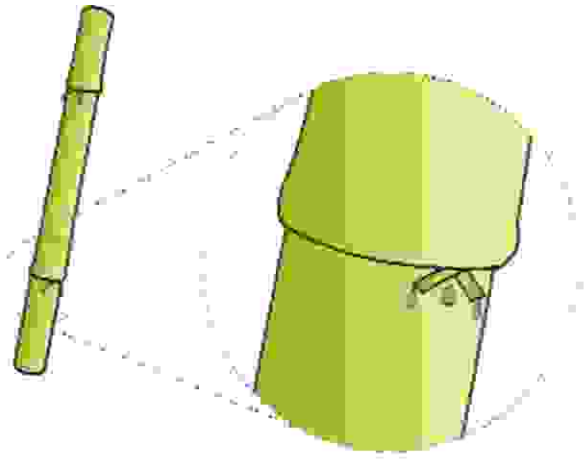
3 Make a fresh base cut and immediately place sections in the solution.

4 25 cm of the bamboo needs to be immersed in the solution.

5 Depending on the length, keep the bamboo immersed for 7-14 days.

6 Stir in between to prevent sedimentation.

7 Drops of solution will appear at the nodes as the solution progresses upward



8 Invert the sections midway.

9 Check the solution strength regularly with a hydrometer. Top the solution daily to replace uptake.

10 Remove the treated bamboo culms .

11 Season under shade.

Alternatively, to accelerate penetration of solution, keep the foliage intact during treatment. But this will make handling and disposal of foliage time-consuming.

Preservatives
10-15% Boric Borax for indoor use
3-5% CCB for indoor use
5-12% CCB for exterior use.

Soaking/Diffusion

Round bamboo, splits and slivers can be treated by keeping them submerged in water-borne preservative solution. The preservative moves into the bamboo due to concentration gradient and the cell sap moves out due to osmotic pressure. The method of diffusion can be varied by increasing the concentration of preservative to reduce treatment time, using two salts to increase fixation and filling the lacuna of the culm with solution by puncturing the nodes to fasten the diffusion process.

Scale: The process is slow, requiring a large number of tanks. It is suitable for treating 50-100 culms a month.

Method

1 Prepare the water-borne solution of preservative in a tank. A tank with an outlet at the base is required for draining of solution and cleaning

2 For round bamboo, puncture the diaphragm with a long rod to improve penetration.

3 Bundle the material and submerge using sinker load.

4 Cover the tank to reduce water loss through evaporation.

5 Sludge may form after a few days especially in fixed type preservatives. Do not stir to disperse the sludge as this may facilitate deposition of particles on the bamboo surface and hinder penetration.

6 Keep the material immersed for 15-20 days for round bamboo, and 7-10 days for splits and slivers. Thin walled culms may require less time.

7 Drain and remove the treated material.

8 Stack horizontally to facilitate further diffusion and air dry under cover.

9 Check the solution regularly with a hydrometer. Top solution daily to replace uptake.

10 Clean tank periodically (4 - 8 weeks) depending on use. Remove sludge and mix it with chromic acid solution to retrieve preservatives. Filter in muslin cloth and reuse solution.

Preservatives
5-8% Boric Borax for indoor use
4-10% CCA for exterior use
3-5% CCB for indoor use
5-12% CCB for exterior use.

Alternative 1: Dip Diffusion

By increasing the solution concentration, soaking time can be reduced considerably. Also, in this way, there will be no contamination of the solution with cell sap and large-scale treatment is possible. This method is not suitable for round bamboo.

Method

1 Dip material for 10 minutes in high concentration solution (15-20% CCB) or 10% Boric acid: Borax at 500C - CCB/ CCA should never be heated

2 Remove and stack the material under cover. The material should be packed tightly to minimise gaps in between

3 Cover the stack with a polyethylene film to prevent drying.

4 Store for 10-20 days to allow diffusion.

5 Air dry

Alternative 2: Double Diffusion

This is two-stage diffusion using two different salts to improve penetration of the preservative so that the treated material can also be used in humid conditions not in soil contact.

Method

1 Soak slivers/strips/round bamboo in a single salt solution 20% Copper Sulphate or Zinc Chloride for 2-3 days.

2 Subsequently soak in a fixing salt like 20% Sodium Dichromate for 4 days.

3 Season for 2-4 weeks under cover to provide time for fixation.

Alternative 3: Vertical Soak and Diffusion Process

Round bamboo can be treated by this method to increase the penetration by diffusion.

Method

1 Pierce the diaphragm of the nodes except the last one.

2 Stack the culms vertically on supports on a shallow sloping basin.

3 Fill the lacuna of the culm with preservative (10% Boric-Borax).

4 Top solution regularly.

5 After two weeks, drain solution into storage tank by inverting the bamboo culm

6 Completely drain solution.

7 Stack horizontally under shade to allow further diffusion and air-drying.

Hot and Cold Treatment

It is based on the principle that on heating, air from the cells will expand and partially escape. During cooling a slight vacuum is created due to contraction of the residual air and causes the entry of preservative into the cell.

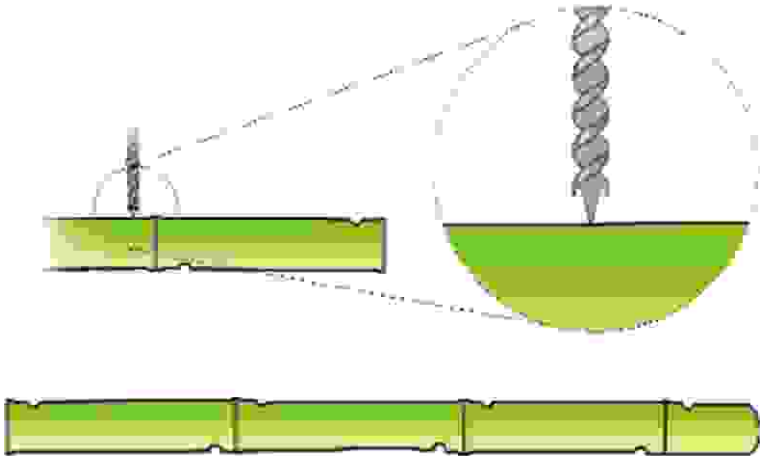
Scale: Large quantities can be treated at one time.

Method

1 For round bamboo - make two holes on opposite walls of each internode near the node or rupture the nodal diaphragm.

2 Air dry the material.

3 An open tank fitted with steam coils or other alternate heating arrangement is required.



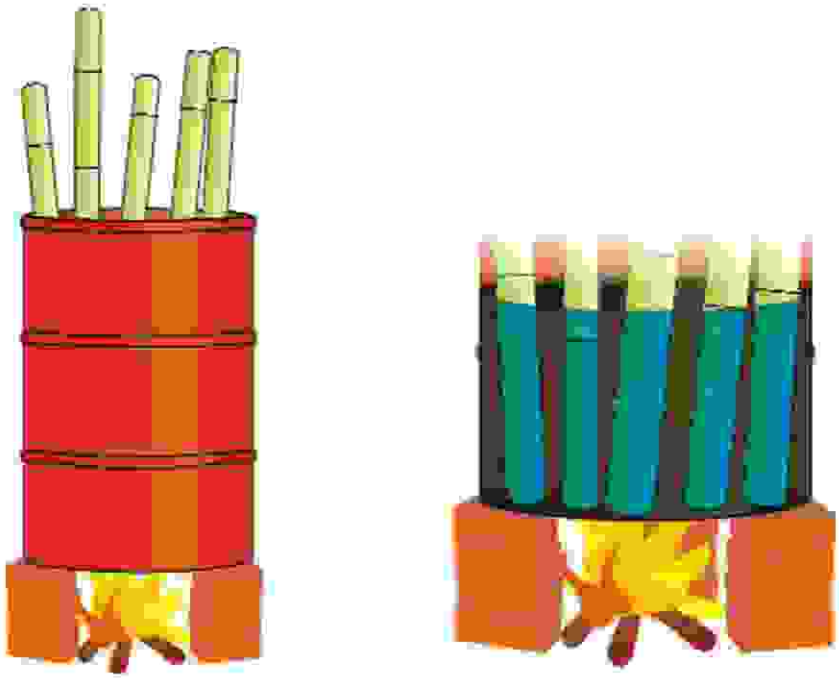
4 Load culms into tank.

5 Fill tank with hot oil - creosote oil or mixed with furnace oil (50:50).

6 Heat to 900^{0}C and maintain for 2-3 hrs.

7 Allow to cool to ambient temperature

8 Drain excess preservative.



Preservatives
Creosote for exterior uses (can be heated to 900^{0}C)
Boric acid-Borax (should be heated to 500^{0}C)

Points to Remember

- Treatment with creosote is most suitable for bamboo used as reinforcement in mud/cement
- Viscosity of preservatives like creosote decreases on heating easing penetration.
- Do not use Dichromate containing salts like CCA and CCB as they precipitate on heating

Sap Replacement Treatment: Modified Boucherie Process

In this method, the preservative is forced under pressure through the entire length of the culm, so that the sap is replaced by the preservative.

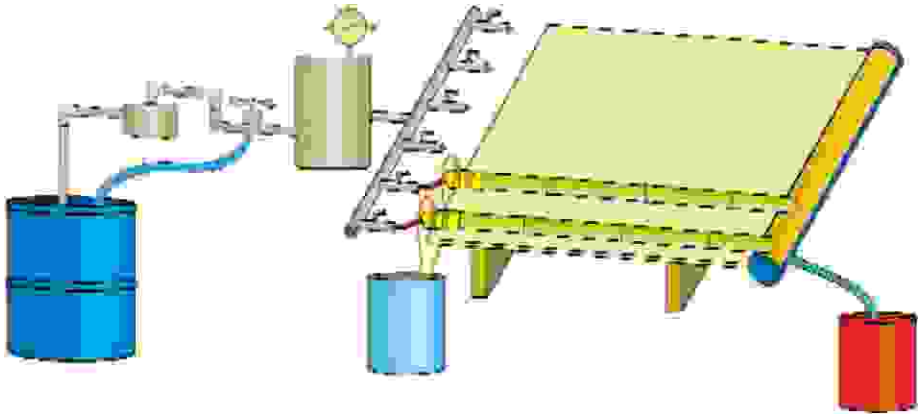
Scale: Up to 5-6 bamboo culms can be treated at a time. Treatment time for 6 m long sections is 3 hrs for interior use and 6 hrs for exterior use.

Equipment

A small pump - a bicycle pump can also be used.

A thick-walled steel tank capable of withstanding 2 kg/cm^2 pressure having an outlet just above the base and fitted with the pump at the inlet.

Rubber hose for connecting the bamboo culms.



Method

1 Prepare the solution of water-borne compositions in a plastic bucket.

2 Store the freshly felled culms in water overnight before treatment.

3 Make a knotch all around the interior side of culm to create additional entry areas for preservative solution Attach one end of a pressure rubber hose to the outlet and the other end to the freshly felled bamboo to be treated without removing the branches.

4 Fill the steel tank with the preservative solution. Bleed entrapped air through the valves.

5 Keep the culms inclined slightly downwards.

6 Pump in air maintaining pressure of about 1-1.5 kg/cm^2.

7 Place a receiving container below the other end of the bamboo culm to collect solution.

8 The preservative will start dripping within 30 minutes.

9 Release pressure and remove the culm when the outcoming solution shows an equivalent concentration as of the incoming solution. Time for treatment would be about 3 hours. (exterior applications 6 hours).

10 Stack horizontally and allow the bamboo to dry slowly under shade to allow lateral diffusion of preservative.

Step 7 may be substituted as below, if uniform retention of preservative is required at both ends of the bamboo culm.

7a. Release pressure after 3 hours.

7b. Add an equal amount of water to the preservative solution remaining in the tank (dilute to 50% strength).

7c. Apply pressure again and maintain for another 3 hours.

7d. Release pressure, remove the culm and allow it to air dry under shade. Preservatives 6-12% CCB for exterior applications 3-5% CCB for indoor use 4% BoricBorax for indoor use.

Points to Remember

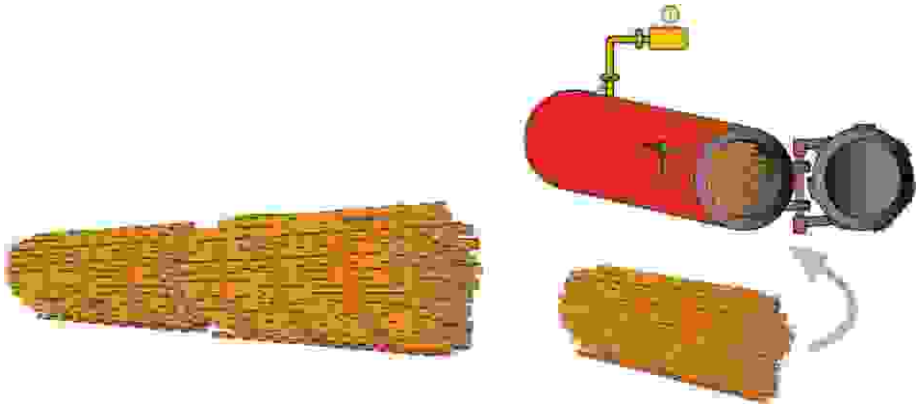
- Treated leaves and branches should be burnt in the open and ashes disposed carefully.
- Only safe preservatives containing Boron should be used.
- Treatment can also be given without pressure. For this a single culm is treated at a time. Treatment without pressure for about 5 m of culm takes 6-7 days.

PRESSURE TREATMENT

Pressure methods are suitable for dry bamboo and ensure quick and uniform penetration of the preservative deep inside. The principle of the process is to force the preservative into the bamboo tissue. This is achieved either by evacuation of the air inside the culm, or by increased pressure upon the preservative in a pressurized cylinder, or a combination of both.

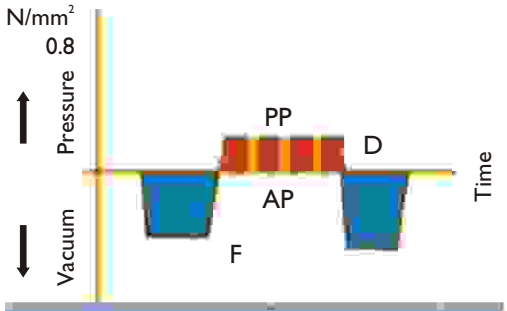
Treatment under pressure increases the durability of bamboo. Bamboo treated by this method will last for about 15 years in ground contact and 50 years for building components. Water-borne preservatives and sometime creosote are used for the treatment.

Depending upon the pressure schedule, the four different types of pressure treatment are there and these are as follows.



Vacuum Process

The culm is first evacuated by creating a vacuum to partly remove air which may restrict entry of preservative solution due to air bubbles. The solution floods into the cylinder and forces into the culm on release to normal pressure. Another cycle of vacuum is repeated to improve penetration and preservative loading.



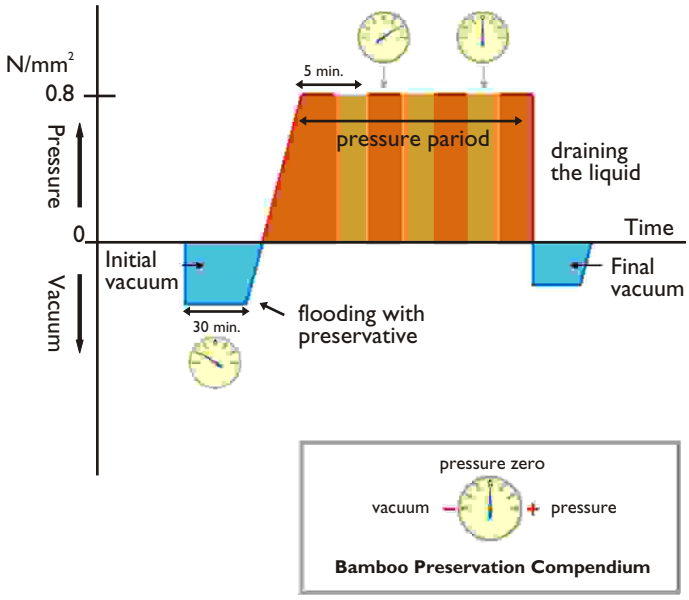
Principle of the treatment diagram for the vacuum process (dashed line optional)

Vi - inital vacuum
F - flooding with preservative
AP - atmospheric air pressure
PP - pressure Period
D - draining the liquid
Vf - final vacuum

Full cell Process

This is similar to the vacuum process in the first stage where the culm is evacuated. In the second stage the preservative is pumped into the culm under a pressure of 5-15 bar for some hours. The purpose is to fill the cell lumens completely with preservative solution. At the final stage, a vacuum is again created for 10 minutes after draining the preservative and to eliminate bleeding by removing excess material.

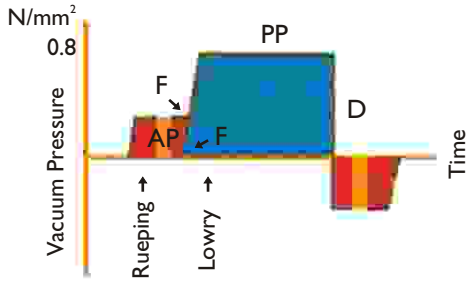
This schedule is used for treating of bamboo culms to be used for structural applications, where high retention and penetration has to be ensured. The preservative in cell lumens is subsequently soaked into adjacent fibres and parenchyma cells.



Empty Cell Process

This process is used where low retention but complete penetration is required. The preservative forms a coating on the cells and does not fill the lumen.

Cost of equipment for this method is higher than for full cell pressure and requires more operational skill.



Principle of the treatment diagram for the empty-cell process (dashed line optional)

Fast Fluctuating Pressure Process

Initially a vacuum is created followed by flooding of preservative at 5-15 bars. This pressure is maintained for a few minutes and then abruptly dropped to atmospheric level. The pressure is again raised and dropped. Many such pressure cycles are administered and with each cycle the pressure holding period is reduced. Vacuum in the final stage prevent dripping. This method is adopted for green bamboo when the moisture content is more than 60%.

Higher concentration salts (8-10% CCA or 5-6% boron salts) are used as the solution becomes diluted with sap from the culm.
Some important points that must be kept in mind for establishment of pressure treatment facility:

- Since the capacity of pressure treatment plants would be higher than non pressure processes, there must be a steady demand for treated material. Unless capacity of the facility is fully utilised, cost of treated culms would not be economical for most commercial purposes

The culms have to be dry with about 20% moisture to allow free passage of the preservative.

- Equipment like a pressure cylinder, vacuum and pressure pumps, mixing and storage tanks, boiler, steam coils and recording instrument are required. The pressure cylinder has to be made of thick sheet so as to withstand the given pressure.
- For plant operation, a trained operator with technical know-how would be required
- Space for storage of material to be processed and already treated
- Due to the cost of supporting equipment, processing area, it will require high initial investment.

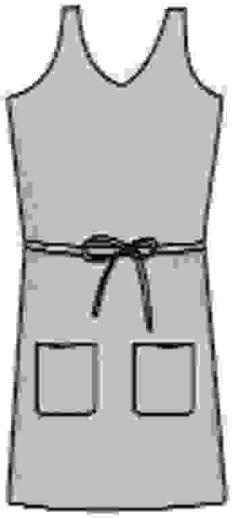
Operation cost will also be power due to the requirement of chemicals and power

Preservatives

Creosote for exterior use
5-8% CCA for exterior use
5-6% under cover construction
2-4% BoricBorax for indoor use.

Pressure treatment equipment is available with standard manufacturers who will also provide assistance for installation, operation and maintenance of the equipment. Refer Annexure 1 for list of manufacturers of pressure treatment plants

13 Handling of Preservatives



HEALTH & SAFETY PRECAUTIONS

All preservative formulations contain toxic components and should be handled with great care. Precautions are necessary during preparation of solution, treating operations and handling.

- The treatment area should be well ventilated with no unauthorized entry.
- Wear aprons, work clothes, gloves, protective goggles, footwear before preparation of solutions, treatment and handling of freshly treated material.
- Spraying of chemicals should be done in the wind direction.
- No drinks or food should be consumed in the treatment area.
- As solvents used in some formulations may be flammable, the treatment area should be declared as no smoking zone.
- Empty containers should be placed out of reach of non-technical personnel and children, and properly disposed of by burying in the ground.
- Skin contact with preservatives should be avoided. In case of any irritation, the skin should be washed thoroughly with soap and water.
- Clean hands with soap, take a shower and change work clothes after finishing the job.

Disposal of preservative after treatment

- Preservative solutions should not be disposed of in drains, rivers/

streams. Used solution may be decanted and reused. Residues may be mixed with saw dust and buried in the ground.

- Sludge generated during treatment should be reclaimed for chemicals and reused by adding Chromic acid and bringing the pH to 2.5.

MIXING OF PRESERVATIVE SOLUTION

The preservative is available as a ready mix or can be mixed by the user. It is always recommended that toxic salts like CCA, CCB, etc., be obtained as a premix and dissolved in water to get a solution. Boric acid: Borax is available as a pre-mix and can also be prepared by the user easily. The purity of the chemicals should be ascertained. Chemicals required for compounding various formulations should have at least 98% purity. Also, the chemicals should always be bought from well-established and reliable manufacturers.

To prepare a solution of any concentration, the weight of the quantity to be dissolved can be found out by the following method:

Assuming

Q = Quantity to be dissolved in water
C = Concentration of solution required
V = Volume of solution to be prepared
S = Concentration of salt/paste
Q = (C x V)/S.

If you have to prepare 8% CCA solution where the strength/ concentration of CCA is, say, 95 and the required volume is 100 litres:

The quantity of CCA to be dissolved in water = (C.V/S) = 8 X 100 / 95

Similarly, for Boric: Borax solution:

Boric acid and Borax are usually mixed in the ratio of 50:50. A ratio of 1: 1.4 has a better solubility in water as it results in the formation of Disodium Octaborate. The salts can be pre-mixed in any of these ratios and dissolved in water. For a 10% solution of Boron formulation, the procedure is as below:

	Boric acid	Borax	Water
For 50:50 ratio	5 kg	5 kg	100 litres
For 1:1.4 ratio	4.2 kg	5.9 kg	100 litres

Boron salts may be heated to about 50^{0}C while making solutions or during treatment to hasten the process. However, beyond 500c it results in loss of salts.

QUALITY CHECK

Quality control is most essential in any industrial product. Inadequately treated material can develop defects in transportation, storage or use. It is

Boric acid has a very low solubility and Borax is mixed to improve the solubility. Variation in mixing ratios may not have much influence on the performance of treated bamboo. The higher the solubility, the better will be the treatment as boron salts penetrate the bamboo structure via diffusion.

therefore essential to have quality checks during and after the treatment process. Several conventional preservatives are easy to detect for their presence with simple spot tests. It is not possible to estimate the amount of preservatives in bamboo treated in the green condition by diffusion methods. The only reliable method is to estimate the same by quantitative analysis, which can be done only in a chemical laboratory. However, in most other treatment methods, it is possible to determine the amount of preserving chemicals in the treated bamboo from the quantity of solution consumed during treatment and the solution strength used.

PENETRATION CHECK

Lack of sufficient loading/distribution of chemicals within the bamboo structure is usually responsible for early failure in use. While penetration and distribution of conventional preservatives can be easily done anywhere, the amount of preservative loaded in the bamboo can be checked only in a full-fledged chemical laboratory. To check the penetration/distribution of preservatives, the bamboo is cut across its wall thickness and staining chemicals are applied. The penetrated portions develop colours indicating the presence of specific chemicals. The procedures for different formulations are detailed in Annexure 2

14 Indian Standards for Preservation of Bamboo

Two related codes for preservation of bamboo and cane have been published by Bureau of Indian Standards

1. Preservation of Bamboo and Cane for Non-Structural Purposes: Code of Practice - IS 1902: 2006
2. Preservation of Bamboo for Structural Purposes: Code of Practice - IS 9096-2006

Annexures

Annexure

ANNEXURE 1: LIST OF TREATMENT PLANT AND PRESERVATIVE MANUFACTURERS

Ascu Arch Timber Protection Limited
P-46 A Radha Bazar Lane, 4th Floor
Kolkata 700001

B.S. Tar Pvt. Ltd.
113 Park Street, 6th Floor
Kolkata 700016.

Borax Morarji Limited
53/57 Luxmi Insurance Building
Sir PM Road, Fort
Mumbai 400001.

dHe American Technologies Inc.
5, Indra Park
Jallandhar City, Panjab

Kartar Engineering Works
16, Industrial Estate
Yamuna Nagar, Haryana 135001.

Kanoria Chemicals and Industries Ltd.
Indra Prakash, 21 Barakhamba Road
New Delhi 110001.

R.D. Industrial Corporation
188 Manicktala Main Road
Kolkata 700054.

R.K. Industries
36 Industrial Estate Phase I
Yamuna Nagar, Haryana 135 001

Winsol Energy Development Group
Plot No. 400/1 & 2, GIDC, Opp. New Water Tank
Vithal Udyog Nagar, Gujarat 388 121

ANNEXURE 2: PENETRATION CHECK FOR DIFFERENT CHEMICALS

Creosote
Presence of creosote is indicated by a dark brownish colour as well its peculiar odour.

Arsenic
Reagents
Solution 1. Dissolve 3.5 g ammonium molybdate in 90 ml distilled water; then add 9 ml concentrated nitric acid.

Solution 2. Dissolve 0.07 g benzidine dihydrochloride in 10 ml concentrated acetic acid and add the solution to 90 ml distilled water.

Solution 3. Dissolve 30 g stannous chloride in 100 ml of 1:1 hydrochloric acid (one part concentrated hydrochloric acid added to one part distilled water).

Best results are obtained with freshly prepared solutions. Agitate the solution until all chemicals are dissolved. Solution 1 must be prepared for each day's testing; solutions 2 and 3 can be stored for a week in clean, glass-stoppered, brown glass bottles.

Procedure
Solution 1 is first applied by dipping the cross-section in a flat glass dish containing the solution or pouring the solution over the cross-section. The entire surface must be saturated. After waiting for two minutes, shake off the excess solution and allow the surface to dry for about one minute.

Solution 2 is next applied in the same manner as solution 1.

Solution 3 is applied last by pouring the solution on the cross-section. The entire surface will immediately turn bluish. Allow some time for the reaction to bring about the maximum colour contrast. Untreated portions will fade to a bright red or reddish-orange, while treated portions will turn light bluish-green to dark bluish-green.

After about one hour, the stain fades; the colours can be renewed by application of solution 3.

Boron
Reagents
Solution 1. Extract 10 g turmeric with 90 g ethyl alcohol. Decant or filter to obtain clear solution.

Solution 2. Dilute 20 ml of concentrated hydrochloric acid to 100 ml with ethyl alcohol and then saturate with salicylic acid (about 13 g per 100 ml).

Procedure
A smooth dry surface shows the results of the spot test better than a rough surface.

Solution 1 is applied, preferably by spraying, or with a dropper, to the surface. The treated surface is allowed to dry for a few minutes.

Solution 2 is then applied in a similar manner to the areas that have been coloured yellow by the application of solution 1. The yellow colour of the turmeric-stained surface is turned red and shows the presence of boron. Placing bamboo in a warm oven accelerates and intensifies the colour reaction to better differentiate between treated and untreated bamboo.

Copper
Reagents
Dissolve 0.5 g chrome azurol S and 5 g sodium acetate in 80 ml water and dilute to 100 ml.

Procedure
Spray the solution over split or freshly cut surfaces of treated bamboo. A deep blue colour indicates the presence of copper.

Chromium
Reagents
Dissolve 0.5 g diphenyl carbazide in 50 ml of isopropy1 alcohol and 50 ml distilled water.

Procedure:
Spray solution of diphenyl carbazide on the dry split bamboo or cross-section to be tested. The treated portions will quickly turn purple, while the untreated areas retain its original colour.

Zinc
Reagents
1g of potassium ferricyanide in 100 ml of water. 1g of potassium iodide in 100 ml of water. Starch indicator solution. Make a paste of 1 g of soluble starch in about 5 ml of distilled water; add 100 ml of distilled water, and boil for one minute with constant stirring. Cool. This solution is subject to decomposition, and therefore should not be used longer than 3 days before a new batch is prepared.

Procedure
The cross-section of bamboo to be tested should be reasonably dry. Mix 10 ml each of the three stock solutions and pour into a good atomizer. Spray the cross-section evenly. The treated surface turns deep blue instantly.

Pentachlorophenol/Trichlorophenol using a Silver-Copper Complex

Reagents
Cupric acetate Cu (CH3COO)2 2H2O
Silver acetate CH3COO Ag
Tergitol XD
Distilled water
Isopropyl alcohol (99%)

Stock Blends

I	II
Cupric Aceatate - 4.0 g	Silver Acetate - 0.4 g
Tergitol XD - 0.5 g	Distilled water - 100.0 g
Distilled water - 100.0 g	

Procedure
Mix cupric acetate and distilled water until dissolved and then add Tergitol XD. The XD is a semi-solid at normal temperatures. Heat this until liquid, and then add to the blend with mixing until solution clears. Reserve as Blend I.

Penta-Check
Blend I - 25
Blend II - 25
Distilled water - 25
Isopropyl alcohol (99%) - 25

Mix in the order indicated and apply to cross-sections of penta-treated surface and observe formation of red colour. Application may be by brush, flow-on or spray.

ANNEXURE 3: CALCULATING PRESERVATIVE RETENTION

Usually preservative loading is reported as the amount of preservative in kilograms in one cubic metre of bamboo. It is therefore imperative to know the volume of bamboo to obtain the preservative loading.

Calculating Bamboo Volume
Round bamboo
Bamboo has a hollow centre and a taper from the base to the top. Each bamboo is unique in terms of internode length, taper and wall thickness at the two ends. A reasonably good estimate of the volume of round bamboo can be made using volume formulae for cylindrical objects. The estimated volume will be slightly less than the actual volume as this formula will not include the volume of nodal membranes separating the inter nodes.

D1 is the outer diameter of the butt end
D2 is the inner diameter of the butt end
D3 is the outer diameter of the top end
D4 is the inner diameter of the top end
L is the length of the bamboo culm

Total (outer) volume of bamboo = 3.14 X [(D1 + D3)/4]2 X L
Inner (hollow) volume of bamboo = 3.14 X [(D2 + D4)/4]2 X L

Actual volume = (Total volume) - (Inner volume).

(A bamboo culm of 4 m length, 6 cm outer and 4 cm inner diameters at butt end, 5 cm outer and 3.5 cm diameter at top end, will have a volume of 0.005 cu m.)

Split Bamboo
It is not possible to estimate the volume of bamboo in the split form. A rough estimate of the same can, however, be made from its weight, density and moisture content.

If Wc (kg) is the weight of the bamboo at current moisture content M, say, 5 kg

M (%) is the moisture percent based on oven dry weight of bamboo, say, 10%

and D (kg/m3) is the density of bamboo say 600 kg/m^3;

the volume can be estimated as below:

Oven-dry weight (Wo) of bamboo =
(100 Wc) / (100 + M) = (100 X 5) / 110 = 4.54 kg

Volume of Bamboo (m^3) = Wo/ D = 4.54/600 = 0.0075 m^3

Estimating Preservative Loading

Retention of preservatives used in solution form can be estimated as below.

Preservative absorbed = Amount of solution absorbed (litres) X Solution strength used (%).

Say, 2.5 l of 5% solution = 2.5 X 5/100 = 0.125 kg

Retention = (Preservative absorbed) / Volume = 0.125/0.0075 = 16.66kg/m3 16.66kg/m^3

ANNEXURE 4: SUMMARY OF RECOMMENDED TREATMENT PRACTICES

Applications	Preservatives	Concentration (%)	Retention (Kg/m^3)	Method
Structures exposed to weather and in ground contact (posts, fences etc.)				
	Creosote	Ready to use	50-100	Hot & Cold
Dry bamboo Diffusion	CCA	10	8-12	Pressure
Green bamboo	CCB	8-10	10-15	,,
Structures exposed to weather but not in contact with ground - bridges, ladders, scaffolding				
	Creosote	Ready to use	50-80	Hot & Cold
Dry bamboo Pressure	CCA	6	8	Pressure
Green bamboo Soaking	CCA	6-8	8	Soaking/Diffusion
Structures under cover - rafters, walls, doors				
Dry bamboo	CCB	5-6	4-6	Pressure
Green bamboo	CCB	6-8	4-6	Soaking/Diffusion
Outdoor furniture				
Dry bamboo	CCA	4-6	8	Pressure
Green bamboo	CCA	6-8	8	Soaking
Indoor furniture				
Dry bamboo	Boric acid/ borax	2-4	4	Pressure
Green bamboo	CCB	3-5	4	Soaking
Handicraft items				
Green/dry bamboo	CCB	6-8	8	Soaking/Dipping
	Boric acid/ Borax (for in contact with edible material)	2-4	4	Dipping

Glossary

a

absorption amount of wood preservative or moisture gained by bamboo during treatment or soaking in water

air-dry a condition of bamboo attained by loss or gain of moisture at ambient atmospheric conditions

air-drying the process of removal of moisture from bamboo by storing under cover at atmospheric conditions

b

beetle an insect, which develops from an egg laid in the bamboo pore, damages the bamboo in larval stage and leaves the bamboo as adult

Biodegradation decomposition of materials by organisms

Boucherie process a process of treatment of wooden poles by gravitational flow of the preservative solutions from the butt end

borer see beetle

brown rot decay caused by fungi consuming cellulose/ hemicelluloses leaving behind lignin

c

cellulose a polysaccharide composed of hundreds of cellubiose units (composed of two glucose units combined in inverted structure)

check a split in the bamboo culm surface formed due to shrinkage during drying or mechanical forces clump several bamboos

culms growing at one site containing culms mature, immature and rhizomes

coating application of solutions or resin finishes for protection against physical/biological damage

collapse a defect produced during rapid drying or application of high pressure during treatment of bamboo under pressure

concentration amount of active ingredients in preservative solutions

cortex outer part of bamboo between epidermis and ground tissue

crack an enlarged check culm a stem of bamboo having nodes and internodes, emerging from buds

curing traditional method of treating bamboo culms

d

decay fungal degradation of bamboo substance

density weight per unit volume of bamboo substance expressed as g/cm^3 or kg/m^3

diaphragm a transverse partition in bamboo culm between two internodes

diffusion a process of treatment of bamboo, in which the preservatives move by diffusion from the solution to the sap in the bamboo structure dipping a process of treatment of bamboo, keeping the bamboo immersed in solutions for varying periods

dosage quantity of chemical to be applied to guarantee toxic effect against target agencies
durability expected life of material during use

e

empty-cell process a pressure process of treatment, where the inner surface of cells get only a coating of the preservative solution
epidermis the outermost layer of the bamboo culm
equilibrium moisture content moisture content of bamboo attained in equilibrium with the surrounding conditions

f

fibre a long cell with lignified walls
fibre saturation point or **FSP** a moisture content condition where all the cell walls are fully saturated with no liquid water in the lumens
fixation a process involving reaction of wood preservatives with bamboo resulting in becoming insoluble in water frass digested waste remains of bamboo produced by borers
full-cell process a pressure process treatment schedule designed to fill all the cells in the bamboo structure
fumigant a chemical formulation which enters the bamboo structure in vapour form
fungi organisms lacking chlorophyll and depending on organic matter for food
fungicide a chemical compound capable of killing fungi and inhibiting their growth

g

graveyard test a field exposure test performed to evaluate the natural durability and performance of preservatives under comparable conditions

h

hot and cold process a treatment process in which the bamboo is subjected to heating (to force out air due to expansion) and cooling (to create a partial vacuum to suck preservative solution) in the preservative solution

i

immature refers to bamboo culm which is less than three years old and lacks complete cell wall development
internode part of the culm lying between two nodes
insecticide a chemical compound or mixture which kills insects and inhibits their multiplication

l

lacuna inner space of the hollow culm
larva a life cycle stage of insect formed after hatching of egg
leachable chemicals being soluble in water and likely to leach out from bamboo in contact with water
leaching a process to remove starch from the bamboo culm
LOSP light organic solvent-based preservatives

m

mature refers to bamboo culm which is over three years old where cell wall development and lignification have been almost completed
moisture content amount of water present in bamboo calculated as percentage of its oven-dry weight
mould a fungus growing on the surface of bamboo in damp

conditions producing coloured spores
mycelium mass of fungal hyphae constituting the body of fungi

n

node partitions appearing in the culm separating two internodes
nodal ridge raised structure at the node

o

oil-based preservative type of preservative in oil form needing no solvents for impregnation of wood
organic solvent-based preservative see LOSP

p

parenchyma living cells in bamboo structure functioning as stores of carbohydrate materials
permeability a measure of the ease of entry of fluids into the bamboo structure
pits an opening connecting two adjacent cells
preservative chemical having toxicity for bamboo-degrading organisms
pressure treatment a process in which the preservative solution is forced into the bamboo structure under externally applied pressure
prophylactic treatment superficial (surface) treatment to prevent biodegradation during storage of bamboo and bamboo products

r

repellant a chemical formulation or surface coating which is unattractive to water/insects
retention amount of wood preservative loaded in bamboo