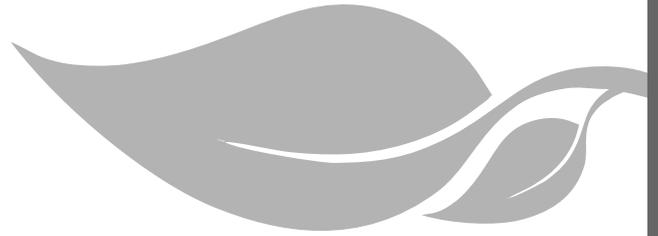




**SEASONING OF
WOOD & BAMBOO**
and
WOOD PRESERVATION
A User Manual

Indian Council of Forestry Research & Education

www.icfre.gov.in



Seasoning of Wood & Bamboo and Wood Preservation

A USER MANUAL



INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION
P.O. New Forest, Dehradun - 248 006

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Foreword



Dr. Suresh Gairola, IFS
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ICFRE with its Headquarters at Dehradun is an apex body in the national forestry research system that promotes and undertakes need based forestry research and extension. The Council that came into being in 1986 has a pan India presence with its 9 Regional Research Institutes and 5 Centers in different bio-geographical regions of the country. Since then research in different fields of forestry has been a major focus of ICFRE.

There is an earnest need of publication of its research to the stakeholders in a simple and lucid manner, to improve the visibility and relevance of ICFRE. Therefore it was decided that the information available on the technologies/processes/protocols/practices developed by ICFRE has to be updated and may be published in the form of operational manuals/user manuals. It was also expressed that the manuals should be a comprehensive national level document depicting extent of knowledge in applicable form.

Accordingly, 18 scientists of ICFRE were nominated as National Subject Matter Coordinators (NSMCs) to carry out the task on the specified subject. These NSMCs were assigned the task to select and nominate nodal officers from other Institutes of ICFRE as well as other organisations if necessary, collect and collate the information on the subject from various sources in coordination with the nodal officers of ICFRE institutes.

A manual on "Seasoning and Preservation" is being brought out in two volumes. Volume-I (Seasoning of wood and bamboo) and Volume-II (Wood preservation)

ICFRE has done pioneering work in developing preservatives and testing their efficacy under various conditions of use and seasoning techniques for different commercial timbers.

ICFRE Institutes have developed and accumulated a vast resource of information and knowledge on seasoning of wood and bamboo and wood preservation. The same has been presented here in this user manual in two volumes.

In VOLUME I - "A User Manual on Seasoning of Wood and Bamboo" attempt has been made to make this user manual very practical and without scientific jargons with an aim that a common man may also be able to follow it easily and, after appreciating the benefits of seasoning and in absence of any



facility of professional kiln dryers, he should be able to season his wood following air seasoning technique. The manual will also be practically useful for Indian solid-wood industry and wood and bamboo handicraft industry for value addition to their products leading to improved quality.

And VOLUME II - " A User Manual on Wood Preservation" is a manual on Wood treatment problems and practices besides development of many new eco-friendly preservatives. This current manual is formatted to serve as a guide to engineers, architects, wood processing industry and future technologists as well as students of wood science and technology and for public to create awareness about wood protection and its advantages.

Further, the manual has got good number of new initiatives to facilitate research through innovation. I hope that the manual will provide useful information to the diverse stakeholders and prove to be helpful literature for planning future programmes in research for development.

Dr. Suresh Gairola

Preface

Volume-I : Seasoning of Wood and Bamboo



It is a matter of immense pleasure for me to prepare a user manual on seasoning of wood and bamboo. Since time immemorial seasoning of wood was in practice in India based on practical wisdom. About 80 years ago attempts were made for scientific seasoning of wood and bamboo in India. Earlier seasoning sheds were popular and afterwards kiln seasoning developed. The Forest Research Institute, Dehradun has contributed a lot in this direction. Research on steam-heated kilns, solar kilns, dehumidifier kilns and vacuum kilns in the Forest Research Institute was very fruitful and the developed seasoning techniques for different commercial timbers have been well adopted by Indian wood industry. Special seasoning and sawing techniques developed for Poplar and Eucalypts saved wood wastage and have been proven very practical for

wood industry in the country. Chemical seasoning of round bamboo for avoiding surface wrinkles and cracks along the nodes is very useful technique for value addition to round bamboo based novelty items and has proven a very beneficial tool for bamboo artisans. Since seasoning process is energy intensive process and adds cost to raw wood, it couldn't be fully implemented across the wood industry. Customer in general is not aware about the benefits of seasoned wood and is not ready to pay extra amount for seasoned wood. Even on date, a common man is dependent on his carpenter's wisdom. From carpenter's point of view wet wood is good as less force is required in cutting, planing, boring a wet wood and carpenter's tools do not get blunt. From customer's point of view seasoned wood is always better than wet wood for making furniture, door and window shutters etc. as strength properties and dimensional stability of seasoned wood are much better compared to wet wood. Attempt has been made to make this user manual very practical and without scientific jargons with an aim that a common man may also be able to follow it easily and, after appreciating the benefits of seasoning and in absence of any facility of professional kiln dryers, he should be able to season his wood following air seasoning technique. The manual will also be practically useful for Indian solid-wood industry and wood and bamboo handicraft industry for value addition to their products leading to improved quality.

My gratitude and sincere thanks are due to Dr. S.C. Gairola, Director General, Indian Council of Forestry Research and Education for inspiration and encouragement to prepare this manual. My sincere thanks are also due to Shri. Arun Singh Rawat, Director, Forest Research Institute for his support and facilitation. The efforts done and support provided by Shri. Vipin Chaudhary, Deputy Director General (Extension) and Dr. Shamila Kalia, Assistant Director General (Media & Extension), Indian Council of Forestry Research and Education is also greatly acknowledged.

Dr. N. K. Upreti
Scientist - G
Forest Products Division, FRI



Preface

Volume-II : Wood Preservation



Forest Research Institute (FRI), Dehradun has done pioneering work in developing preservatives and testing their efficacy under various conditions of use. Since last hundred years, the WP branch of Forest Products Division of FRI has developed and accumulated a vast resource of information and knowledge on wood treatment problems and practices besides development of many new eco-friendly preservatives. Thus, this current manual is formatted to serve as a guide to engineers, architects, wood processing industry and future technologists as well as students of wood science and technology and for public to create awareness about wood protection and its advantages.

The enclosed sections in the manual provide an understanding of current wood preservation practices in the wood preservation industry. This manual will apply primarily to wood-based materials used in construction and other commodities. The information contained herein is basic and practical and is

not intended to serve as a complete guide to wood preservation workers. It is always the wood traders and preservers responsibility, by law, to read and follow all current label directions for the specific preservative being used. In the present time the importance of wood preservation has increased many times because, when nondurable plantation grown or imported timber left untreated in many outdoor applications, wood becomes subject to degradation by a variety of natural factors. Although some tree species possess naturally occurring resistance to decay because of extractives, many are in short supply or are not permitted to harvest .

Most commonly used wood species, such as teak, sal, and sisoo, possess sufficient decay resistance hence extra protection is not required when they are exposed to adverse environments, thus categorized as durable timber and generally treatment is not required. However, nondurable wood can be protected from the attack of decay fungi, harmful insects, or marine borers by applying chemical preservatives. The degree of protection achieved depends on the preservative used and the proper penetration and retention of the chemicals. Some preservatives are more effective than others, and some are more adaptable to certain use requirements. Not only are different methods of treating wood available, but treatability varies among wood species-particularly their heartwood, which generally resists preservative treatment more than does sapwood. Manual contains details of treatability aspects to obtain long-term effectiveness, adequate penetration and retentions for wood species, chemical preservative, and treatment method. Wood preservatives that are applied at recommended retention levels with satisfactory penetration can greatly enhance the life of wood products. Thus, the annual replacement cost of treated wood in service is much less than that of wood without treatment. The main chapters contain basic structure of wood and properties, biological decay of wood by fungi and insects, classification of timber on the basis of natural durability, treatability of wood, choice of method and equipment, calculation of preservative solution concentration, change of solution strength, evaluation of preservative retention and penetration, preparations before wood treatment, preservatives types, methods of application of preservative in wood treatment and protecting human health and the environment. The author expresses her deep sense of gratitude to Dr. S. C. Gairola, Director General , Indian Council of Forestry Research and Education (ICFRE) for inspiration and valuable suggestions for formulation of manual. My sincere thanks are due to Director, Forest Research (FRI) Institute Dehradun Shri Arun Singh Rawat for his valuable suggestions. The efforts and support provided by Deputy Director General (Extension) Sh. Vipin Chaudhary and Assistant Director General (Extension) Dr. Shamila Kalia is greatly acknowledged.

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COMPILED BY

VOLUME - 1

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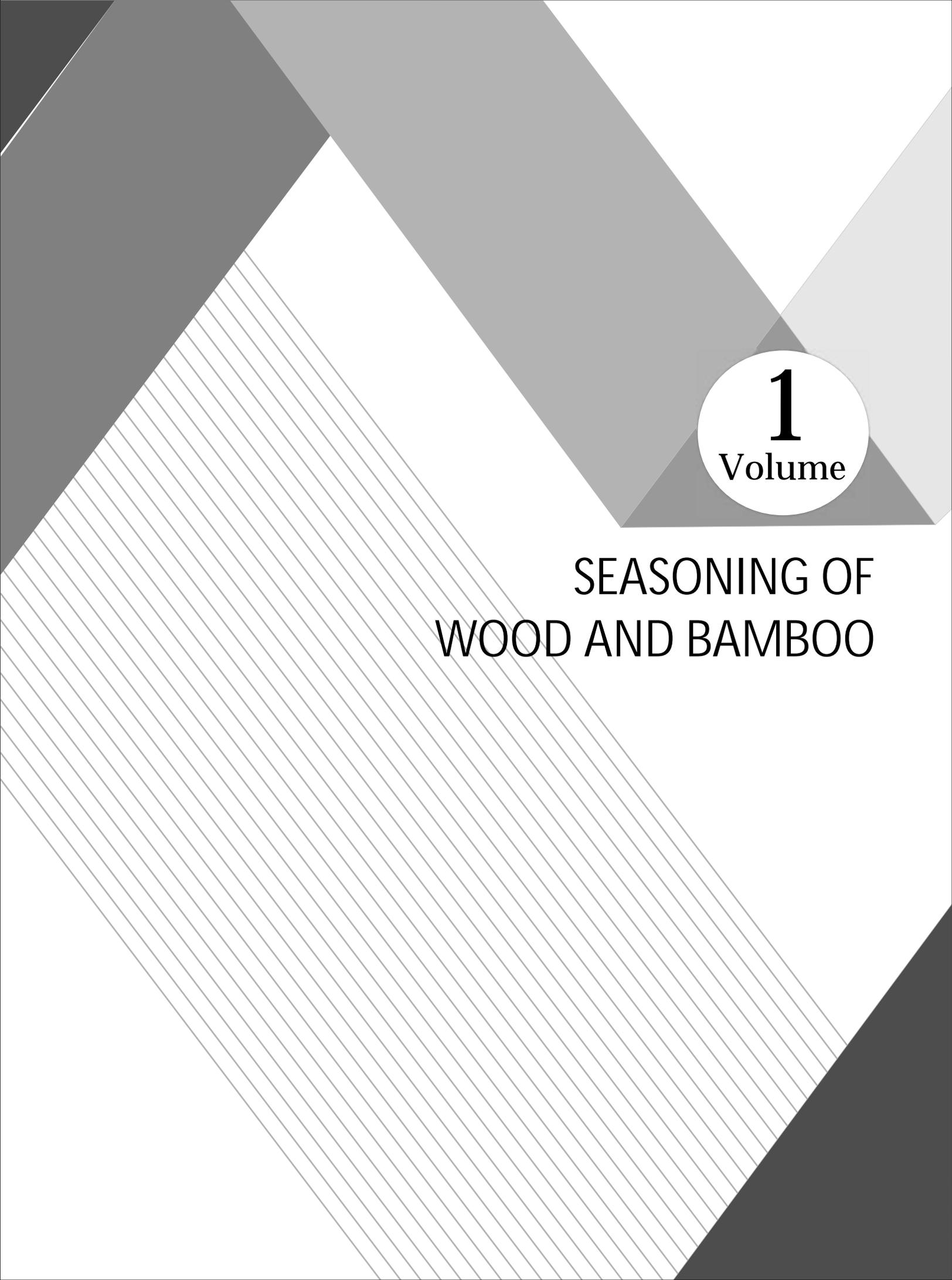
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The cover features a large, light gray triangle on the left side, filled with fine, parallel lines. The rest of the cover is white, with several dark gray geometric shapes: a large triangle at the top left, a smaller triangle at the top right, and a triangle at the bottom right. A white circular badge is positioned in the upper right area, containing the text '1 Volume'.

1
Volume

SEASONING OF
WOOD AND BAMBOO



1 INTRODUCTION

Seasoning of timber is essentially a drying process of timber wherein undesired water present in freshly cut timber is gradually removed in controlled manner so that timber becomes fit for making any product. Freshly cut wood may contain as much water as up to two-third of its un-dried volume in form of moisture.

Before making a product out of wood, it passes through series of processing steps like sawing in required sizes in a saw mill, seasoning of wood in a kiln, product manufacturing (cutting, thickness, sanding, boring, mortising etc.) finishing. After sawing of timber, it is sent to kilns for seasoning process wherein undesired water present in wood is removed to certain level to make the timber suitable for making a product. If product is made without seasoning the timber, the product fails due to its poor strength properties and other physical qualities. For example, if a cricket bat is made out of unseasoned *Salix alba* wood, its impact strength will be poor and the bat will not give the desired stroke for hitting a ball out of boundary.

Freshly felled timber contains large quantity of moisture, in many cases moisture content in wood is more than 100% based on the oven-dried weight of the timber. For the satisfactory performance of the timber, it is essential to remove this excess water from the timber before making any product out of it. Seasoning improves overall quality of timber and makes it fit for making a good quality product. It is like 'older is the rice better is its quality' in terms of taste and texture after cooking. The older rice gradually gets seasoned with time in go downs that's why it is costlier than the fresh rice.

This user manual on seasoning of wood and bamboo will prove a very practical guide for handicraft industry, solid wood industry, bamboo artisans and saw millers. This manual will also serve the quest of a common man having 'Do It Yourself' attitude, as the method of natural air seasoning can easily be followed for his need of seasoned wood specially when facility of professional wood dryers becomes unapproachable. .

It is appropriate to say that wood seasoning is an art highly blended with science. It requires lot of practice to become an efficient wood seasoning kiln operator. The scientific input to an experienced kiln operator saves lot of wood from wastage.



2 BASICS OF SEASONING

Wood Seasoning is gradual removal of moisture from timber without degrading health of timber.

DIFFERENCE BETWEEN DRYING AND SEASONING

Both the processes are essentially same but seasoning is little more than drying. Let us understand this by one practical example of our day-to-day life. After taking shower bath in the morning, we generally hang our towel under the Sun for drying so that it can be reused next time. In case of a dark colored shirt, we dry it under shade after washing it because we are concerned about its color and it should not fade. In drying we are not bothered about the health of wood whereas in case of seasoning we take lot of care of health of wood so that it should not develop defects like warping, end splitting etc. Thus in drying, water is removed from wood in uncontrolled manner often resulting drying degrades in wood where as in seasoning water is removed from wood gradually in controlled manner so that drying degrades are under control.

BENEFITS OF SEASONING

Freshly felled timber contains large quantity of moisture, in many cases it is more than 100% based on the oven-dried weight of the timber. For satisfactory performance of timber it is essential to remove this excess water from timber when in the green condition. During the removal of this moisture, wood shrinks and if the process of drying is not properly carried out in a specific controlled manner, this shrinkage results in several defects and degrades in the timber. Wood seasoning is one of the most important processing steps wherein wood is dried to a specific moisture content depending on the surrounding atmospheric conditions in a controlled way. The primary objective of wood seasoning is to enhance the wood properties, minimizing any quality losses and thereby make timber more valuable. Some of the major advantages of wood seasoning are as follows:

- Timber with less than 20% maximum content (MC) has no risk of developing stain, decay or mould as a result of fungal activity.
- Seasoned timber is typically more than twice as strong as wet timber.
- Seasoning improves nail and screw holding properties of wood.
- Seasoned timber is lighter and hence transportation and handling cost are reduced.
- Wood seasoning results in dimensional stability in timber while in service. Products made from wet wood often shrink substantially as the wood dries.
- Gluing, machining and finishing are much easier to accomplish with seasoned wood.
- Timbers which are to be chemically treated with wood preservatives have to be properly dried to allow for quick penetration of the treating chemicals.
- Seasoned timber exhibits better electrical and thermal insulation properties.

3 FACTORS AFFECTING DRYING RATE OF TIMBER

In case of commercial production of wooden articles, seasoning of timber plays an important role in value addition to wooden articles. In business, time is an important factor. Seasoning of timber generally takes many days and is more time consuming and energy intensive process as compared to other processes of product manufacturing. Hence, it becomes essential to understand the factors affecting drying rate of timber. Drying rate of timber is volume of moisture removed from timber per unit time. Normally it is represented by moisture content percentage removed per day (MC %/Day). The three essential things required for seasoning of timber are: heat, air flow, humidity. Heat works as a force to bring out moisture from core of wood to its surfaces. Air flow helps in transferring the heat evenly through wood stack in kilns, and humidity maintains the health of timber by avoiding over-drying of timber and release of tension from timber inside a kiln.

The rate of drying of wood is governed by an interaction of the external drying conditions, viz., temperature, relative humidity, rate of air circulation, and the rate of moisture diffusion within the wood, as detailed below-

TEMPERATURE

If relative humidity is kept constant, the higher is temperature the higher is drying rate. Temperature influences the drying rate by increasing the moisture-holding capacity of air, as well as by accelerating the rate of diffusion of moisture through the wood.

RELATIVE HUMIDITY

If temperature is kept constant, lower relative humidity results in higher drying rates. This is affected by increased moisture gradient in wood, resulting from the reduction of moisture content of surface layers when the relative humidity of air is reduced.

AIR CIRCULATION

With constant temperature and relative humidity, the higher possible drying rate is obtained by rapid circulation of air across the surface of the wood. This is brought about by the rapid removal of moisture evaporating from the wood, so that the relative humidity of air in contact with wood is not allowed to rise beyond the relative humidity being maintained in the body of the drying air.

SPECIES

Some species dry much faster than others. This is mainly related to the resistance which wood offers to moisture diffusion, which is governed by the dimensions, alignment and structure of capillary system of wood, and the nature and extent of plugging of this structure by gums, extractives, organic growth like tyloses, pit aspiration, etc.

INITIAL MOISTURE CONTENT

The amount of moisture contained in wood affects the time required to bring it to given moisture content. As a general rule, wood dries at a faster rate when green. The rate decreases with decrease of moisture content under constant drying conditions. This is because initially the evaporation from green wood is confined to the surface layers, which can dry by direct evaporation of the moisture into the surrounding air. Afterwards, the rate of outward diffusion of moisture within the



wood becomes controlling factor, as moisture has to be brought out from the interior to the surface for further evaporation.

GRAIN DIRECTION

Wood dries much more rapidly in the longitudinal direction than in transverse direction. The rate of drying from end-grain is 10 to 15 times faster than from the radial or tangential surfaces. In practice, however, timber is mostly sawn with its length conforming to the general direction of grain and with the width and thickness transverse to the grain. Because of the large difference between longitudinal and transverse dimensions, drying of timber in common commercial size timber occurs mostly from its lateral faces by transverse movement rather than from the end-grain faces by longitudinal movement of moisture

THICKNESS

Thicker timber requires more time to reach given moisture content than the thinner timber.

4 CLASSIFICATION OF WOOD SPECIES BASED ON THEIR REFRACTORINESS TO SEASONING

For the purpose of seasoning, timbers are classified into three classes depending upon their behaviour with respect to cracking and splitting, and drying rate while seasoning (IS 1141:1993):

CLASS A (HIGHLY REFRACTORY WOODS)

These are slow drying timbers and difficult to season free from cracking and splitting. Examples are heavy structural timbers, such as Sal (*Shorea robusta*) and Laurel (*Terminalia alata*). Their permeability (ease of movement of water inside wood) is very poor. They are kiln dried using Schedule no 5, 6, 7 as given in IS:1141. They take lot of time (28-35 days) to season in the range of 12-8 % moisture content.

CLASS B (MODERATELY REFRACTORY WOODS)

These timbers may be seasoned free from surface and end cracking within reasonable short time periods, given a little protection against rapid drying conditions. Examples are moderately heavy furniture class of timbers, such as Shisham (*Dalbergia sissoo*) and Teak (*Tectona grandis*). They are kiln dried using schedule no. 3 and 4. They take 18 -25 days to season in the range of 12-8 % moisture content.

CLASS C (NON-REFRACTORY WOODS)

These timbers may be rapidly seasoned free from surface and end cracking even in open air and sun. If not rapidly dried, they develop blue stain and mould on the surface. Examples are light broad leaved (hardwood) species for packing cases, such as Semul (*Bombax spp.*) and Salai (*Bosewellia serrata*), and almost all coniferous species. They are kiln dried using schedule no. 1 and 2 and take 5-8 days to season in the range of 12-8 % moisture content.



5

METHODS OF DETERMINATION OF MOISTURE CONTENT IN WOOD AND BAMBOO

Before seasoning of timber and bamboo, one needs to know the moisture content present in the wood and bamboo.

There are many devices present in the market for the purpose, like pin type moisture meters and sensor based moisture meters. These meters have their own working limitations also. The method of oven drying the timber for moisture determination, as recommended in IS: 11215, 1991 is more reliable as it is based on average weight loss of timber during oven drying.

In this method, 12 to 20 mm long moisture strip is cut from middle portion of a timber length and weighed in a digital balance with least count of 1 mg. The strip is then kept inside a laboratory oven for drying in a temperature $103 \pm 2^\circ\text{C}$. After 24 hours of oven drying, the strip is taken out and weighed again. Then again it is kept inside the oven in same temperature and weighed in every two hours till its weight becomes stable (does not decrease further). The stable weight indicates that all the moisture present in wooden strip has been removed and its moisture content at this stage is practically zero. This final weight is called its oven-dried weight.

The formula explained in Bureau of Indian Standards (IS: 11215, 1991) is used for calculation of moisture content (MC) in wood samples.

$$MC (\%) = \frac{(\text{Initial Weight} - \text{Ovendry Weight})}{\text{Ovendry Weight}} * 100 \dots\dots\dots(1)$$

where initial weight refers to weight of sample before any particular drying treatment is initiated and oven-dry weight refers to the constant weight achieved by the sample after drying it in an oven at $103 \pm 2^\circ\text{C}$ temperature.

TYPES OF WATER IN WOOD

In freshly cut wood, water is present in two forms. The water which is present inside cell cavities (lumens) and is free to move easily is called free water. The water present inside the cell wall and is chemically bonded with wood material is called bound water. When wood is seasoned, free water starts coming out first followed by bound water. During kiln drying process, it is costlier to remove bound water from wood compared to free water as removal of bound water requires more time and energy and at the same time health of timber is to be maintained during removal of bound water.



Laboratory oven

EQUILIBRIUM MOISTURE CONTENT

When wood is exposed to air at a constant temperature and relative humidity (RH), the wood will lose (or gain) moisture until it reaches moisture

equilibrium with the surrounding air. At equilibrium moisture content (EMC), the moisture in wood is in equilibrium with the Relative Humidity (RH) of the surrounding air. There is no transaction of moisture between wood and surrounding atmosphere at EMC of wood. A slight change in RH and/or temperature of surrounding air disturbs this equilibrium and the process of transaction of moisture again starts between wood and surrounding air.

FIBER SATURATION POINT

The moisture content of wood at the point at which all the free water has been removed from the fiber cavities and, cell walls are fully saturated with bound water is known as the 'Fiber Saturation Point (FSP) of the wood and is different for different wood species. It is highly critical point in the drying of wood as wood begins to shrink from this point onwards as the swollen fibers start releasing moisture. During commercial drying of timber, more attention is required below its FSP. Fiber saturation point varies with wood species. It has been also found to vary within the same species of wood obtained from the different regions.



6 WOOD SEASONING METHODS

As a thumb rule, a wood is supposed to be seasoned when its moisture content is in the range of 8 % – 12 % with respect to its oven dry weight and is fit for making any indoor used product. The maximum permissible moisture content allowed in any product is given in IS: 287 and is a reference guide for how much seasoning is to be done on a timber meant for an end product.

To avoid manufacturing problems with the finished products, especially warping, splitting and checking, timber must be dried to a final moisture content that is close to the middle of the range of moisture content values. A finished product should not have moisture content more than the recommended value. India has been divided into four climatic zones based on annual average relative humidity from the point of view of the optimum moisture content for seasoned wood.

The zones are:

Zone I	Places in India where average annual RH is less than 40%
Zone II	Places in India where average annual RH is between 40 to 50%
Zone III	Places in India where average annual RH is between 50 to 67%
Zone IV	Places in India where average annual RH is above 67%

The moisture content may be higher for special user other than furniture, cabinet, and millwork such as timber used for bending or destined to be exported. Typical desired final moisture content values for these kinds of products are listed in Table below. Once timber is properly dried, it must be stored, manufactured and warehoused at humidity conditions that are at or slightly below the expected in use humidity conditions. Failure to adhere to these maximum permissible moisture content values will result in serious economic losses for the manufacturing firm due to defects in products.

This table was formulated long ago when a typical wood product was not travelling far off places. Now, a product can travel any part of the Globe within a month through ships. Hence, column of Zone 1 is more relevant for commercial timber dryers. They must follow moisture content recommended in this column for different products while kiln seasoning their timber.

SEASONING PROCESS

The seasoning of timber is a two-stage process involving-

- The movement of moisture from the interior to the surface of the planks.
- The evaporation of the moisture from the surfaces to the moving air stream.

When wood dries, surface zones dry in advance of the interior because of direct evaporation of moisture at the surfaces. As a result, a moisture gradient is set up which causes the moisture to move from the interior to the surface, these

Table
Recommended
maximum
permissible
moisture
content in
wood products
(Source-IS: 287)

Use	Moisture Content (%)			
	Zone I	Zone II	Zone III	Zone IV
Aircraft	12	12	14	15
Agricultural implements	12	14	16	16
Artificial limbs	8	10	12	12
Automobile bodies				
• 50 mm and above thickness	10	12	14	14
• Thinner than 50mm	8	10	12	12
Doors and windows				
• More than 50mm thickness	10	12	14	16
• Less than 50mm thickness	8	10	12	14
Furniture and cabinet making	10	12	14	15
Shuttles and bobbins	8	10	12	12
Sports goods	10	12	14	16
Ship and boat building	12	14	16	18
Handles	12	12	14	15
Toys, carved items, pencils	8	10	12	12

processes take place concurrently, but it is essential that the rate of evaporation be controlled and in balance with the rate at which moisture moves to the surface. If evaporation is too rapid, excessively steep moisture gradients will result and this will be accompanied by drying stresses, which may exceed the tensile strength of wood causing checking and related damage to the timber. At any time, drying may be due to one or more of these possible processes: Evaporation, Mass flow or Diffusion.

In drying process above FSP, free water may move through the cell cavities via the intercommunicating pit openings under capillary pressure gradient in a mass flow. Below the FSP, water can move as vapour through cell cavities, and as bound water diffusion through the finer capillaries of the cell walls.

The relative importance of diffusion and mass flow within the wood depends on the permeability (ease of movement of water inside the timber being seasoned) of the timber. With highly permeable timbers the mass flow component within the wood is of great significance in the early period of drying.

$$\text{Rate of drying} \propto 1/\text{density} \propto 1/\text{thickness}$$

(Since, more cell material is traversed per unit distance and this offers resistance to diffusion).

The quantity of water to be removed is proportional to the density of the timber and the thickness of the timber. Even with a permeable timber, diffusion assumes increasing importance as the average moisture content approaches FSP while



drying. Indeed, in those parts of timber where the moisture content approaches FSP the drying is diffusion controlled.

Permeable and impermeable timbers of similar densities should dry from FSP at about same rate. In practice, drying is rarely controlled by a single process. A convenient empirical approach is to assume that the time to dry is proportional to $(\text{density})^n$ and $(\text{thickness})^n$. The value of power coefficient is generally about 1.5.

STACKING OF TIMBER

Stacking technique is most important single factor in satisfactory air seasoning of timber. Proper stacking of timber ensures uniform drying and reduces seasoning degrades considerably, particularly warping and biological deterioration through mould and stain. The rate of drying can be controlled to a certain extent by regulation of the rate of air circulation through the stack by adjusting the height of the foundation, width and height of stack, thickness of spacers and spacing between the adjoining planks in a layer to suit individual cases. In most of the cases of timber (planks, poles, sleepers etc) horizontal stacking is in practice.

The stacking should be done on level foundation over skids (longitudinally placed scantlings) having cross-section of about 10 cm x 10 cm. Spacers (also known as crossers) should be of seasoned and reasonably strong timber, of uniform thickness of cross section, say 2.5 cm x 2.5 cm, for stacking planks up to 5 cm thickness. The distance between the successive crossers in a layer should be about 60 cm for 2.5 cm thick planks. For thicker planks the spacing may be increased to 75 cm. Planks thinner than 2.5 cm should be stacked with crossers spaced less than 60 cm apart to prevent or minimize warping and sagging of planks.

The crossers should be in vertical alignment in a stack. As far as possible, the stack should be constructed so that the ends and sides of stack are "boxed", with the ends of timber nearly sandwiched between the lines of spacers. This is termed as box piling. In case of mixed lengths, longest planks should be at bottom and the shortest at the top. In order to cope with the heavy inflow of timber, and also where the stacking operations cannot be stopped for particular lengths of planks, the stacks may be made separately for long, medium and short lengths timbers. The same holds good for mixed thickness also. Heavy beams should be placed in well distributed form at the top of the stack to prevent top layers from warping. The stack should be raised to convenient heights. The width of individual stack should not ordinarily exceed 1.5 m, but if it does, an open space, about 25 cm wide, should be left in the middle of the stack from top to bottom to permit good air circulation in centre of the stack.



Stacking of timber using spacers

AIR SEASONING

The technique of air seasoning consists mainly in making a good stack of sawn timber with the help of spacers on raised foundations, in a clean and dry place, under shade (like a verandah). As atmospheric air is the drying agent, the rate and quality of drying largely depend on the climatic conditions. Even so, losses of timber through cracking, splitting, warping, decay through fungal and insect attack can be considerably minimized by proper attention to the method of stacking, protection of stacks against the sun and hot and dry winds, and sanitary conditions in the yard. In case of forced-air drying, pedestal fans are used to speed up the drying of timber stack. It is always advisable to apply two coats of bitumen paint on both the cross sections of each log before the onset of cracks at the ends. This saves wood from wastage. In absence of professional kiln dryers, a common man can plan ahead before the construction of house and furniture, and air-season his wood by stacking it in above manner in a place where stack is neither exposed to direct sun light nor to rain. Depending on climate of the place, wood stack takes about 10 to 24 months to naturally season and becomes fit for making household furniture, door and window shutters etc.

KILN SEASONING

Commercial drying of timber is done on big capacity kilns. Capacity of kiln is volume of timber which can be seasoned at a time in a kiln. For example, a 2000 cft capacity kiln can season 2000 cft of timber at a time.

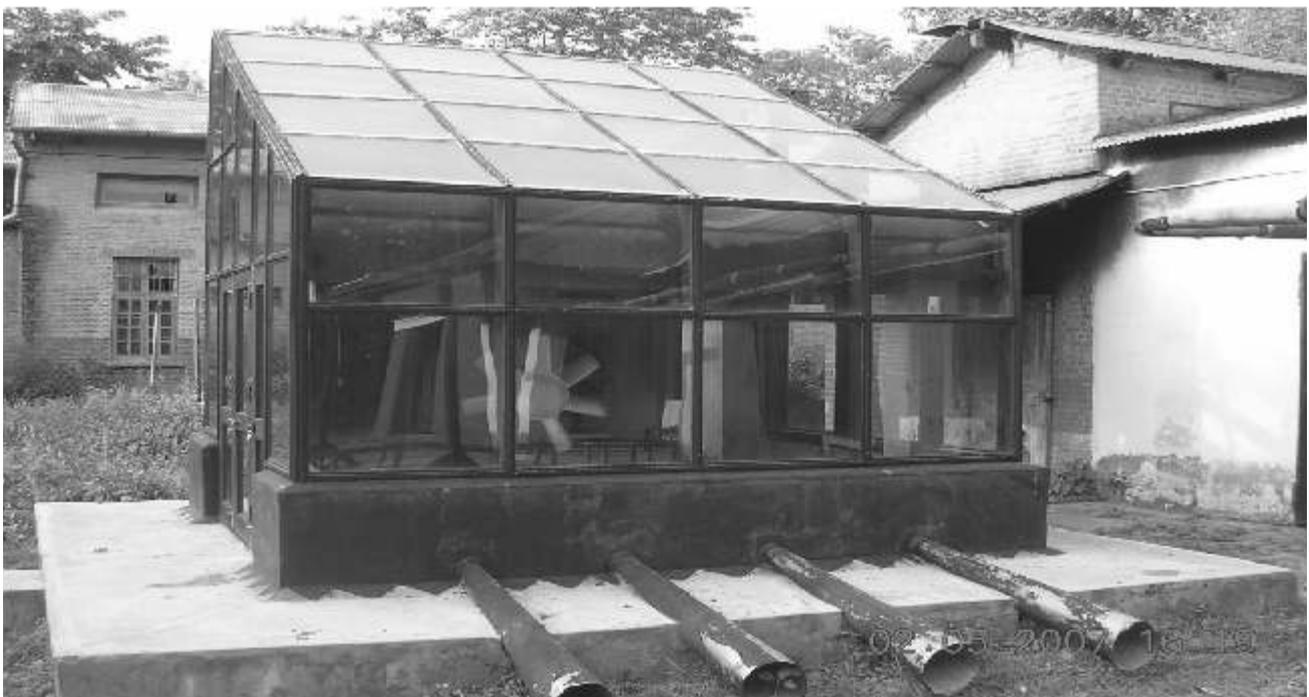
In kiln seasoning, drying of timber is done by using heat generated from source like steam, electricity, solar energy etc. The timber is stacked in chambers, called seasoning kilns fitted with equipment for manipulation and control of temperature and relative humidity of the drying air, its circulation through the timber stack, and partial venting. Kiln seasoning provides a means of overcoming the limitations imposed by vagaries of the weather in open air seasoning. In kiln seasoning, the drying of timber is practically at a faster rate than in air seasoning without increased degrade. This is obtained by the accelerated rate of diffusion of moisture from the interior to the surface as a result of increased temperature of the timber. There is flexibility of control over relative humidity conditions, and also a well distributed uniform air circulation through the stack. This allows the surface moisture content to be controlled despite the higher temperatures and the faster drying, during those stages in drying which are critical for the development of cracking degrade. The advantages of kiln seasoning are rapidity, adaptability and precision. The temperatures employed inhibit and often kill insects and fungi, so that sterilization (at least partial) is achieved simultaneously with seasoning. Kiln seasoning enables wood to be dried to any desired moisture content regardless of weather conditions.

TYPES OF KILNS

As per the heating source, the name of a kiln is given. Solar kiln, Steam-heated kiln, Dehumidifier kiln, Electrically heated kiln, Vacuum kiln are different types of seasoning kilns being used by wood industry all over the world. Depending on the requirement of seasoned timber per month, the type of kiln is preferred. Solar kiln is the cheapest kiln available for wood seasoning compared to any other commercial kiln. This is suitable for small scale rural saw millers and handicraft industry. Timber seasoning cost in a solar kiln works out to be one third of the cost which comes in a steam-heated kiln. Solar kiln takes more time in terms of days to season a timber to desired moisture content compared to steam-heated kiln. Also a solar kiln works for only nine clear months in North India and has to be closed during rainy season. Dehumidifier kiln is run by electricity but it is energy saving kiln. Due to incorporation of heat-pump in it, heat is not lost during typical venting operation in a dehumidifier kiln which is not possible in steam-heated kilns and solar kilns normally. Vacuum kilns are fastest among all types of commercial kilns being used in wood industry. High vacuum helps in speeding up drying process by sucking loosely bound water molecules from wood surface. Also, the emissions from vacuum kiln are nil just as in case of Solar kiln. High capacity vacuum kilns require huge drying vessel and high horse power vacuum pumps, hence are costlier affair above 150 cft capacity kiln.



FRI Solar Kiln



FRI modified Solar Kiln

SEASONING OF WOOD AND BAMBOO



FRI PCM (Phase Change Material) based latest Solar kiln



FRI convection heating based vacuum kiln



Hot press (conduction heating) type Vacuum kiln at FRI

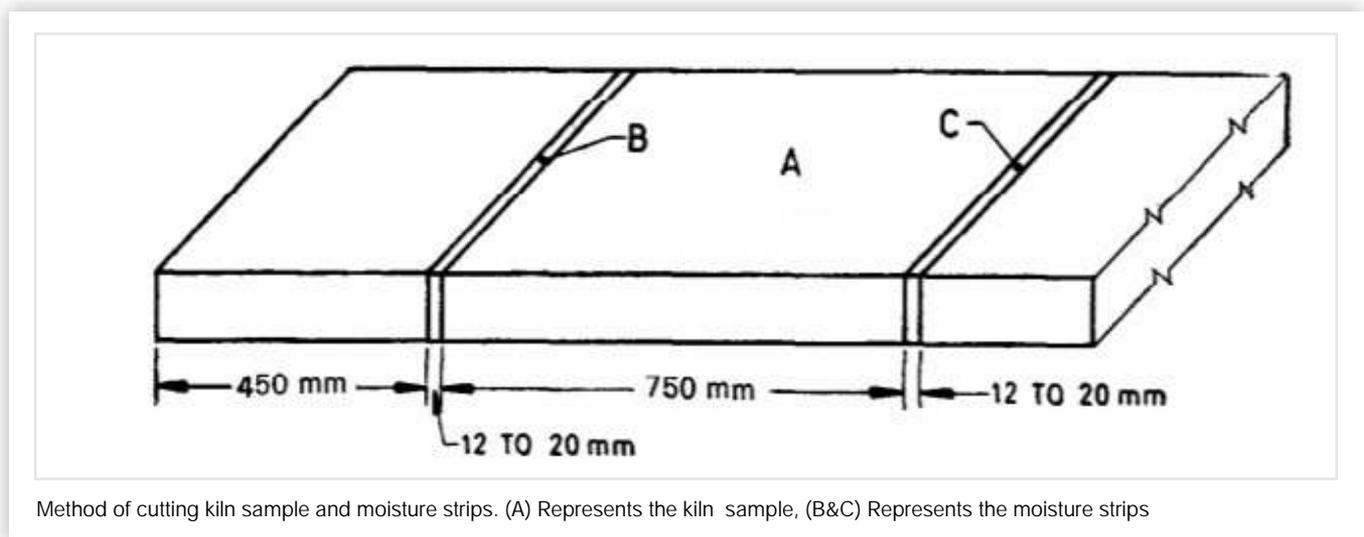


Timber stack ready for keeping inside the Hot press type vacuum kiln

PREPARATION OF KILN SAMPLE

Kiln sample works as a probe for measurement of daily moisture content of timber being dried inside a kiln. It is prepared as per the specifications given in IS: 1141 of 1993.

As per IS: 1141, the wettest and the heaviest sound planks are selected to make kiln samples. 75 cm long sample is cut from a distance of at least 45 cm from one end of each plank from its centre as illustrated in figure below. At the same time as this sample is cross cut from plank, a full cross-section (called moisture strip) measuring 12 to 20 mm along the length of plank is cross cut from near both ends of the kiln sample. The kiln sample and the two moisture strips so obtained are marked accordingly using marker pen for ease of identification.



The number of kiln samples needed for any kiln charge depends upon the condition and drying characteristics of the timber, the performance of the dry kiln, and the final use of the timber. Practically 6 kiln samples should be prepared for 500 cft of wood stack in a kiln. This gives accurate average of moisture content of planks being kiln seasoned.

Samples are selected from the thickest, wettest and slowest drying stock in the kiln charge. In general heart wood samples with slowest rate of drying are preferred to sapwood. Samples selected should be free from knots and other natural defects

The number and the placement of kiln samples inside stack in a kiln is very important aspect. In a 500 cft capacity kiln at least 6 kiln samples must be used and this number should be repeated for every additional 500 cft of timber to be dried in a kiln. The samples must be placed in stack so that they are well distributed along the height and breadth of kiln stack so that while averaging the daily moisture content of these samples, one must get true idea of average moisture content of all the timber planks of a stack inside a kiln.

After kiln samples are cut, end coated and weighed they are placed in sample pockets. Sample pockets are usually placed at several locations along the length of the kiln on both sides of the stack. Since the kiln samples are intended to be representative of timber being dried, they should at all times be exposed to the same drying conditions as the rest of the timber in the kiln.

A check test should be made towards the end of drying for average MC, moisture distribution in the section and casehardening on all the kiln samples. Three complete test cross sections. 12-20 mm long in the direction of grain are



cross cut from a point at least 16 cm one end of each kiln sample . One of the three test sections is weighed immediately after cutting and then oven dried to determine the average MC in the whole section. The second test section is subdivided into shell and core zone (if thickness is 40 mm or less) or shell, intermediate and core zone (if thickness is > 40 mm). The two outside portions of the shell are weighed together and their OD weight is calculated. Similar calculation is also made for intermediate zones. But core is weighed as single piece for its oven dry weight calculation. The third section is marked and sawn so as to produce 3 prongs of equal thickness is 40 mm or less, and six prongs if thickness is > 40mm. The middle prong in the former case and second and fifth prongs in the latter are broken out. The shape of prong sections is traced in a paper and then prongs are allow to dry for 24 hours in room temperature and after that their shape is again traced adjacent to their original shape for comparison. Based on comparison in shape, the change is noticed and degree of casehardening is arrived at. Following is the key for determining the probable condition of developed stress from prongs:-

1. When the prongs turn out on sawing : The surface is in tension (attempting to shrink), and the center is in compression (opposing surface shrinkage).
 - If the prongs turn in after room drying : Indication of unequal moisture distribution, with the surface drier than the center.
Occurrence : In the early stages of drying.
Remarks : The timber does not need steaming at this time. If a tendency to surface check is noticed, use a higher humidity to retard surface drying.
 - If the prongs do not change after room drying : Indication of practically equal moisture distribution, with the surface in tension and the center in compression.
Occurrence : After over steaming at a low moisture content.
Remarks : The timber should have received less severe steaming treatment.
2. When the prongs turn in on sawing : The center is in tension (attempting to shrink) and the surface is in compression (opposing center shrinkage).
 - If the prongs pinch tighter after room drying : Indication of unequal moisture distribution, with the surface drier than the center.
Remarks : An advantageous point to relieve stresses by steaming.
 - If the prongs become straight or turn out after room drying : Indication of unequal moisture distribution, with the center drier than the surface.
Occurrence : After steaming and before re-drying.
Remarks : After re-drying the prongs should remain practically straight.
3. When the prongs remain straight on sawing : The timber is free from stresses.
 - If prongs remain straight after room drying : Indication of freedom from stresses, with equal moisture distribution.
 - If the prongs turn in after room drying : Indication of unequal moisture distribution, with the surface drier than the center.
Remarks : A short steaming treatment to balance the moisture content should relieve all stresses.

- If the prongs turn out after room drying : Indication of unequal moisture distribution, with the center drier than the surface.

Occurrence : During some period of re-drying after steaming.

(Source: Anonymous, 1929)

KILN RECORDS

Good record keeping of kiln run details can be useful to the kiln operator in several ways, such as for modifying drying schedules on subsequent charges to obtain faster drying without sacrificing quality and for checking kiln performance for causes of non uniform drying or drying defects. During the drying time of each kiln charge records of the following items should be kept.

- Dry bulb temperature and Wet bulb temperature of entering air
- Stoppage of working parts in the kiln
- Weight and calculations made in the preparation of kiln sample
- Periodic weighing and moisture content data of kiln samples
- Results of check test



7 KILN SEASONING SCHEDULES FOR INDIAN TIMBERS

In chapter 4 we have seen that wood species have been broadly divided in three categories based on their refractoriness to seasoning. This classification helped in understanding the drying nature of species. However, during commercial seasoning of timber in kilns, we come across many drying defects if seasoning is not done cautiously. For Indian timbers seven seasoning schedules have been developed for their kiln seasoning. A seasoning schedule is a guide chart for kiln operator to operate his kiln so that drying defects are under permissible limits in kiln seasoned timber. These recommended seasoning schedules have been given in BIS standard IS:1141 of 1993. Schedule I is fastest and recommended for timber species having very good permeability (ease of movement of water inside wood) and are very easy to dry defect-free. Schedule VII is slowest and recommended for timber species having very poor permeability and very difficult to dry defect-free.

The kiln-drying schedule is a guide chart with respect to the temperature and humidity conditions to be maintained in a steam-heated kiln when the moisture content of the wettest samples of wood on the entering airside in the kiln has reached the stage specified in the schedule.

It may be noted that the kiln schedule is only rough guide for running a seasoning kiln while drying a certain species of timber at particular moisture content. The schedule is to be regulated in the light of the progress of drying, formation of moisture pockets, quality of timber, purpose for which timber is required, type of kiln, and several other factors like the permissible seasoning degrade and the speed of air circulation employed in the kiln. For this reason the operation of a seasoning kiln should be entrusted to a trained operator.

The seven seasoning schedules are given as below (Source: IS 1141 of 1993):-

SCHEDULE - I

These timber will take 4 to 5 days to season. Initial steaming of kiln charge for 2 hours at 55°C and 100 % RH should be carried out to kill mould growth and equalization of surface MC of all the planks.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	52	4	62
60	55	45	55
40	60	46	44
30	65	48	39
20	68	48	33.5

SCHEDULE - II

These timber will take 5 to 7 days to season. Initial steaming of kiln charge for 2 hours at 55°C and 100 % RH should be carried out to kill mould growth and equalization of surface MC of all the planks.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	45	40	72
60	47	40	64
40	49	40	56
30	53	40	44
20	58	40	32.5

SCHEDULE - III

These timber will take 8 to 10 days to season. In addition to initial steaming, one intermediate steaming and one final steaming towards the end of kiln charge for 2 to 3 hours at 55°C and 100 % RH should be carried out.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	42	38	76
60	45	40	72
40	47	40	64
35	49	40	56
30	51	40	50
25	53	40	44
20	55	40	39

SCHEDULE - IV

These timber will take 12 to 15 days to season. In addition to initial steaming, one intermediate steaming and one final steaming towards the end of kiln charge for 2 to 4 hours at 55°C and 100 % RH should be carried out.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	42	38.5	80
60	42	38	76
40	45	40	72
35	47	40	64
30	49	40	56
25	52	40	47
20	55	40	39



SCHEDULE - V

These timber will take 13 to 16 days to season. In addition to initial steaming, two intermediate steaming and one final steaming towards the end of kiln charge for 2 to 4 hours at 55°C and 100 % RH should be carried out.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	42	38.5	80
45	45	40	72
35	46	40	68
30	48	40	60
25	50	40	53
20	52	40	47
15	55	40	39

SCHEDULE - VI

These timber will take 16 to 20 days to season. In addition to initial steaming, two intermediate steaming and one final steaming towards the end of kiln charge for 2 to 4 hours at 55°C and 100 % RH should be carried out.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	40	37	82
60	40	38	76
40	45	40	72
35	46	40	68
30	47	40	64
25	48	40	60
20	50	40	53
18	52	40	47
15	55	40	39

SCHEDULE - VII

These timber will take 24 to 30 days to season. In addition to initial steaming, at least three intermediate steaming and one final steaming towards the end of kiln charge for 2 to 4 hours at 55°C and 100 % RH should be carried out.

Moisture Content of the wettest timber on air inlet side (%)	Temperature (°C)		Relative Humidity (%)
	Dry Bulb	Wet Bulb	
Green	40	38	88
60	41	38	82
40	42	38	76
35	45	40	72
30	45	40	68
25	47	40	64
20	50	42	61
18	52	42	54
15	55	42	45

All the above schedules are for 2.54 cm (1 inch) thick planks. For thicker planks, schedules are fine tuned as per IS:1141.

Schedule I is for species used for packing case manufacture.

Schedule II is for species used for light planking or moderately heavy type of packing cases.

Schedule III is for species used for most light furniture.

Schedule IV is for species used for common furniture.

Schedule V is for species used for furniture, constructional work, bobbins and other turnery articles.

Schedule VI is for species used for structural purposes and heavy planking.

Schedule VII is for several heavy and highly refractory timbers.

Following table gives details of few species and kiln drying schedules recommended for them:-

Kiln Drying Schedule No.	Species recommended for kiln drying
I	Fir, <i>Allanthus</i> spp., <i>Alnus</i> spp., Semul and didu, paper mulberry, white dhup, Spruce, lambapatti, amra, gutel,
II	Kadam, salai, rudrak, bakota, <i>ficus</i> spp., mango, chir, kail, poplar, vellapine
III	Mundane, chalpash, kathal, deodar, cypress, gamari, silver oak, kanju, jhingan, <i>machilus</i> spp., raini, willow, hillock, hemlock,
IV	Kokko, kala siris, safed siris, amari, aini, poon, chestnut, khadig, satin wood, chickrassy, rosewood, shisham, white cedar, eucalyptus hybrid, benteak, <i>morus</i> spp., padauk, chilauni, bahera, white chuglum, dudhi,
V	Maple, haldu, lakooch, birch, boxwood, cinnamom, gurjan, hollong, rubber wood, walnut, kaim, teak, toon,
VI	Babul, horse chestnut, kumbi, ebony, marblewood, dhaman, jarul, bijasal, Indian oak, mahogany, arjun, laurel, ber
VII	<i>Acacia tortilis</i> , axel wood, amaltas, sundry, hopea, sal, rohini, jamun,



8

WOOD SEASONING DEFECTS : CAUSES, PREVENTION AND REMEDIES

The greatest challenge in kiln drying of timber is to dry the timber defect free. This requires a lot of experience and blending of wood science. Following are the main defects which a kiln operator comes across during commercial drying of timber:

Drying Defects	Causes	Prevention	Possible Remedies
<p>Case-hardening: The condition existing in wood in which the outer layers have undergone rapid drying and become set without corresponding shrinkage, causing stress between the inner and outer layers. It causes warping of the wood when further converted.</p>	<p>Too rapid surface drying owing to use of too low humidity in early stages and / or too high temperature in later stages.</p>	<p>Use higher humidity in early stages and limit temperature in final stages.</p>	<p>At the end of the kiln run long conditioning period or a relief treatment viz., raise temperature and humidity for 2 to 6 hours according to severity of stresses.</p>
<p>Surface Checking: A separation of the fibers along the grain forming a crack or fissure in the wood not extending through the piece from one surface to another. It occurs across the rings of annual growth.</p>	<p>Too rapid drying of surface in relation to the core.</p>	<p>Use higher humidity in early stages.</p>	<p>No cure obviously. Checks will tend to close when wood is fully dried to uniform moisture content.</p>
<p>End Splitting: A separation of fibre along the grain forming a crack or fissure that extends through the piece from one surface to another. A split at the end of a piece of wood is called end a split.</p>	<ul style="list-style-type: none"> • Ends drying more rapidly than the rest • Overhanging ends • Too much circulation of air over ends and too little through stack. 	<p>Paint ends with bituminous paint.</p> <p>Stack properly with spacers at or very near to ends of rows.</p> <p>Baffle off ends and make all air go through stack.</p>	<p>None</p>

SEASONING OF WOOD AND BAMBOO

<p>Honey Combing: Separation of fibers (checks) in the interior of the wood induced by drying stresses when the outer layers have become case-hardened.</p>	<p>Severe case hardening in early stages followed by internal checking from excessive stress in centre. Too high temperature in final stages.</p>	<p>Use higher humidity in early stages. Periodic steaming and limit final temperature.</p>	<p>None</p>
<p>Cupping: A curvature occurring in the cross section of a piece of wood.</p>	<p>Differential shrinkage across grain in tangential and radial directions.</p>	<p>Cannot be prevented but all forms of distortion can be minimized by the following: Stack very carefully, place spacers at frequent intervals and perfect vertical alignment, place spacers at ends of all planks. Place heavy weights on the top of the stacks.</p>	<p>Apply conditioning treatment and if stacking is not proper dismantle it and restack properly before steaming.</p>
<p>Spring: A curvature of a piece in the plane of its edge. Bow: A curvature of a piece of wood in the direction of its length.</p>	<p>Differential shrinkage along the grain owing to irregular or curved grain or reaction wood.</p>	<p>-</p>	<p>-</p>
<p>Twist: Spiral distortion along the grain of a piece of wood.</p>	<p>Spiral grain or inter locked or irregular grain.</p>	<p>Use lower temperature schedule. Place heavy weights on the top of the stacks.</p>	<p>Condition to the correct moisture content.</p>
<p>Mould Growth</p>	<p>Poor circulation of air, very slow drying at moderate temperatures.</p>	<p>Speed up circulation. Use higher temperature if spices are not liable to warp or collapse badly.</p>	<p>-</p>

Source: Gnanaharan *et. al*, 2002



9 SEASONING OF BAMBOO

Green bamboo may contain 50-150 % of moisture. As in the case of wood, seasoning of bamboo is necessary before its efficient utilization.

Round bamboo is often baked over open fire, after applying linseed oil, for primary protection against fungal decay and insect attack during short-term storage. Apart from rapid drying of the outer portions, the slight charring caused is believed to provide some protection against bio-degradation. It is, however, neither a universal technique applicable to all bamboo species without degrade nor is it a method for complete seasoning. Baking should be carried out only over a gentle fire, otherwise severe collapse occur irrespective of the species or the maturity of culms.

AIR SEASONING OF SPLIT AND ROUND BAMBOO

Air seasoning of split or half round bamboo does not pose much problem but care has to be taken to prevent fungal and insect attack during seasoning. Fungal and insect attack can be controlled by rapid drying in open sun as usually adopted for several handicraft items like baskets, mats, chicks, etc. Seasoning of round bamboo presents considerable problem. A study on seasoning behaviour of *Dendrocalamus strictus*, *D. hamiltonii*, *D. membranaceus*, *D. calostachyus*, *D. longispathus*, *Bambusa nutans*, *B. tulda*, *B. arundinacea* and *B. polymorpha* indicated that immature bamboo gets invariably deformed in cross section and thick walled immature bamboo generally collapses. Thick mature bamboo tends to crack on surface with the crack originating at the nodes and at decayed points. Moderately thick immature and thin and moderately mature bamboo season with much less degrade. Bamboo with poor initial condition on account of decay, borer hole, etc. generally suffer more drying degrades. Round bamboo should be kept in vertically standing position for air-drying.

CHEMICAL SEASONING OF ROUND BAMBOO FOR ITS VALUE ADDITION

Seasoning of round bamboo poses considerable problem in several species of bamboo. Many species of bamboo are more or less liable to surface cracking during drying. Some species like *Bambusa nutans*, *Bambusa tulda* and *Dendrocalamus giganteus* crack more than the others. Unlike timbers, drying under mild conditions cannot always prevent cracking in round bamboo. End splitting, surface cracks and cracking at the nodes are common problems faced during air-drying even at slow rate of air seasoning and mild weather. Due to these problems, artisans are not able to use these species of bamboo for novelty items like flower vase, table-lamp stands etc. Chemical seasoning of bamboo properly solves the problem of surface cracks and wrinkles in bamboo.

The process of air or kiln seasoning the wood after treatment with anti-shrink chemicals, chiefly with the object of minimizing seasoning degrades, is known as "Chemical Seasoning". Chemical seasoning of round *Bambusa tulda* in green condition to avoid surface cracks, splitting and fungal discoloration has been tried. A solution made by dissolving 40 % urea and 2 % of boric acid (W/V) in water was used as anti-shrink and anti-borer treatment. This treatment enables forced-air-drying (using electric fans for 7-8 days) of the bamboo with negligible drying degrades whereas the untreated bamboo shows drying degrades unacceptable to be used in round form for novelty items like flower vases.

In this method freshly felled green mature culms of bamboo (*Bambusa tulda*, *Dendrocalamus giganteus*) are converted into small pieces of length 40-50 cm with one end open and another end with a node (example of flower vase). The nodal partition was kept intact. These pieces are dipped for 72 hours in a mixed solution of urea (40% w/v) and boric acid (2% w/v) in water maintained at 45°C initially for 8 hours. Temperature is used for creating a partial vacuum inside the bamboo so that absorption of chemicals would be increased. Boric acid treatment prevents borer attack in subsequent use of the

bamboo. After treatment the treated pieces are wrapped in polyethylene sheets and kept indoor for better diffusion of chemicals. After a week these pieces are forced air dried using electric fans. After drying the product is coated with polyurethane coating in order to avoid problem of sweating during rainy season.

Chemical seasoning method is very useful in avoiding cracks during drying of round bamboo. However, it is suggested that anyone planning to use the treatment commercially should make a series of tests on the species size and shape of specimens to be used, varying the chemical concentration and the treatment time in order to attain an optimum bulking concentration of the chemical.



Chemically seasoned round bamboos for handicraft items



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Stacking of Timber



FRI Solar Kiln



FRI Modified Solar Kiln



Conduction heating based vacuum kiln at FRI



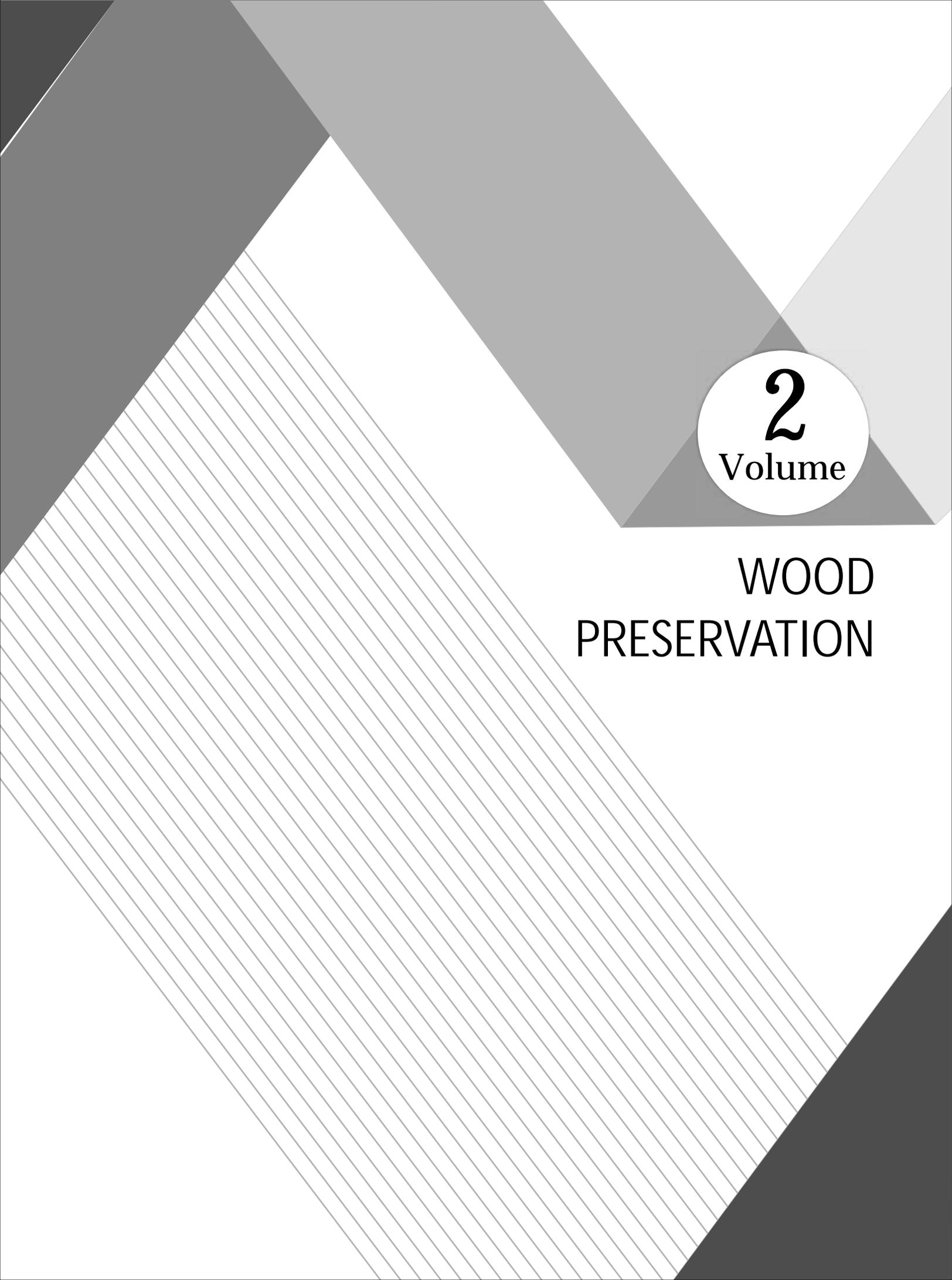
FRI PCM based Solar Kiln



FRI Convection heating based Vacuum Kiln



Timber stack ready to place inside the hot press type vacuum kiln

The cover features a large, light gray triangle on the left side, filled with fine, parallel lines. The rest of the cover is white, with several dark gray geometric shapes: a large triangle at the top left, a smaller one at the top right, and a triangle at the bottom right. A white circular badge is positioned in the upper right area, containing the number '2' and the word 'Volume'.

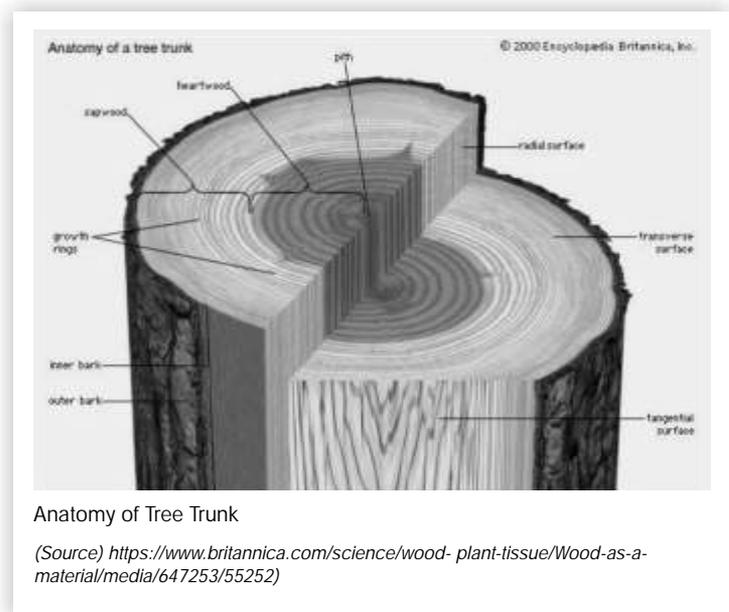
2
Volume

WOOD
PRESERVATION

1 INTRODUCTION

BASIC STRUCTURE OF WOOD AND PROPERTIES

Wood is a fibre-composite material consisting of mainly cellulose fibres in a lignin matrix with complex structure. Macrostructure examination of a cross cut stump or the transverse section (cross section) of tree stump shows mainly innermost part i.e pith followed by heart and sap wood and the outermost is bark. The outer most layer of any tree is bark followed by sap wood which is closest to the edge is moist, light, living layer packed with tubes called xylem that help a tree pipe water and nutrients up from its roots to its leaves; inside the sapwood there's a much darker, harder, part of the tree called the heartwood, which is dead, where the xylem tubes have blocked up with resins or gums and stopped working. Pith is comparatively small and located at the centre of the transverse section. Wood is marked by the presence of concentric layers known as growth rings or annual rings.



TYPES OF WOODS

Wood is divided into two distinct kinds called hardwood and softwood, though confusingly the names don't always refer to its actual hardness or softness: It's generally true that hardwoods are harder than softwoods, but not always, both have distinct internal structures. *Coniferous* trees are softwoods, with vertical cells, tracheids. These cells are used for support and conduction; they have an open channel and a thin cell wall. The limited number of cell types makes softwoods more difficult to differentiate from one another. Hardwood structure is more complex than softwood structure, and varies considerably between species. The majority of hardwood volume is composed of fiber cells that offer structural support to the stem. The major difference between hardwoods and softwoods is the presence of vessel elements, or pores, that exist in hardwoods only.

Hardwoods

Typically come from broad-leaved (deciduous) trees (those that drop their leaves each fall, also known as angiosperms because their seeds are encased in fruits or pods). Examples include ash, beech, birch, mahogany, maple, oak, teak, and walnut.

Softwoods

Typically come from evergreen (coniferous) trees (those that have needles and cones and retain them year-round, also called gymnosperms. Examples include cedar, cypress, fir, pine, spruce, and redwood.



CHEMICAL COMPOSITION OF WOOD

There are two major chemical components in wood: lignin (18–35%) and carbohydrate (65–75%). Both are complex, polymeric materials. These chemical components may divide majorly into:

Cellulose

It is the chief cell wall component (40 – 45 %). This cellulose structure favors the organization of the individual cellulose chains into bundles with crystalline order held together by hydrogen bonds, leading to a fibrous state.

Hemicelluloses

Associated with the cellulose in the cell wall are carbohydrate polymers known as *hemicelluloses*. They consist, for the most part, of sugars other than glucose, both pentoses and hexoses.

Lignin

It is the third major wood cell wall component. It serves as a cement between wood fibers, as a stiffening agent within fibers, and as a barrier to the enzymatic degradation of the cell wall.

Extractives

Extractives are regarded as non-structural wood constituents and usually represent a minor fraction in wood. Wood may contain extractives – extraneous wood components that may be separated from the insoluble cell wall material by their solubility in water or organic solvents. Furthermore, various parts of the same tree, e.g. stem, branches, roots, bark and needles, differ markedly with respect to both their amount and composition of extractives. Heartwood functions in the long-term storage of bio-chemicals known collectively as extractives. The location of the extractives may be in heartwood, the resin canals of softwoods, or as reserve materials in the living portion of the wood (sapwood). Major categories of extractives include volatile oils, terpenes, fatty acids and their esters, waxes, polyhydric alcohols, mono- and polysaccharides, alkaloids, and aromatic compounds.

2 BIOLOGICAL DECAY OF WOOD BY FUNGI AND INSECTS

Wood is an organic material derived from mature trees and has essential component of cellulose, hemicellulose, lignin and extractives. Cellulose is a food source for many organisms which cannot make their own food. Some of these organisms are decay agencies which mainly consume wood material and causes degradation of wood ultimately affecting wood strength. The decay is a natural and essential process by which the dead organic material is recycled. Till the tree is alive, it has got its own resistance power against a wide variety of decaying organisms. While after felling the wood material is liable to decay.

WOOD INHABITING FUNGI

Ascomycetes and Fungi Imperfecti

Certain lower forms of fungi develop as molds and stains on wood. The most important stain is blue stain, although several other colours of stains may also develop in certain wood species. Such attack is confined basically to sapwood of certain wood species, rich in starch content. The cell wall is not attacked, although the stain fungi may penetrate deep into the wood. Such attack occurs when the wood is freshly cut and contains high moisture content.



Sapstain on freshly converted Wood Plank



Decay by Fungi in Field Condition

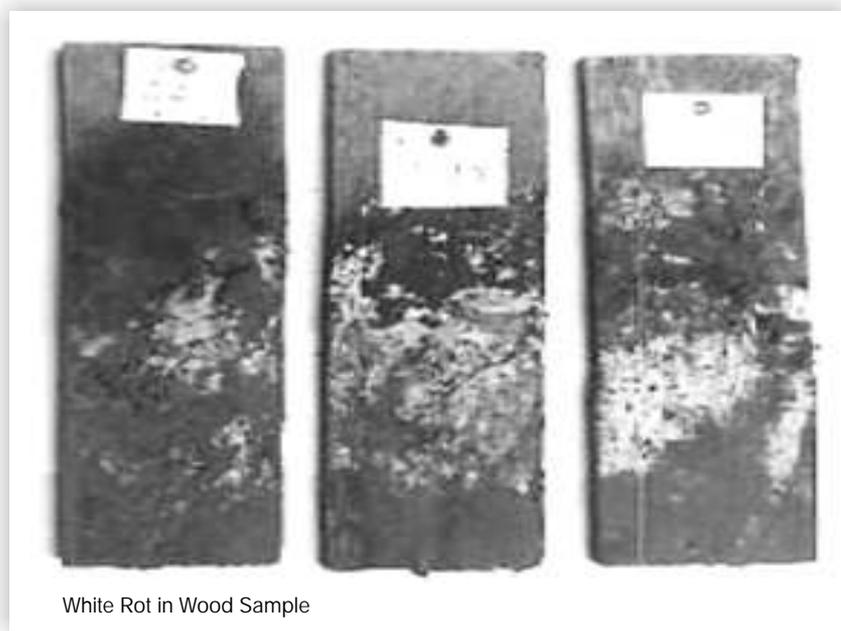
Wood Rot or Decay Fungi

These are the fungi, which thrive on wood substance. Wood decay can occur both during storage or use, whenever conditions for such growth are favourable. Favourable conditions for decay are optimum temperature, (16 to 32°C), moisture (35-45 percent), adequate supply of air and food material in the form of carbohydrate and lignin. Wood rotting fungi are sub-divided into three main types.



White Rot

These attack all components of wood, i.e. cellulose, hemicelluloses and lignin. The wood is reduced to a spongy or fibrous condition with white pockets or streaks.



White Rot in Wood Sample

Brown Rot

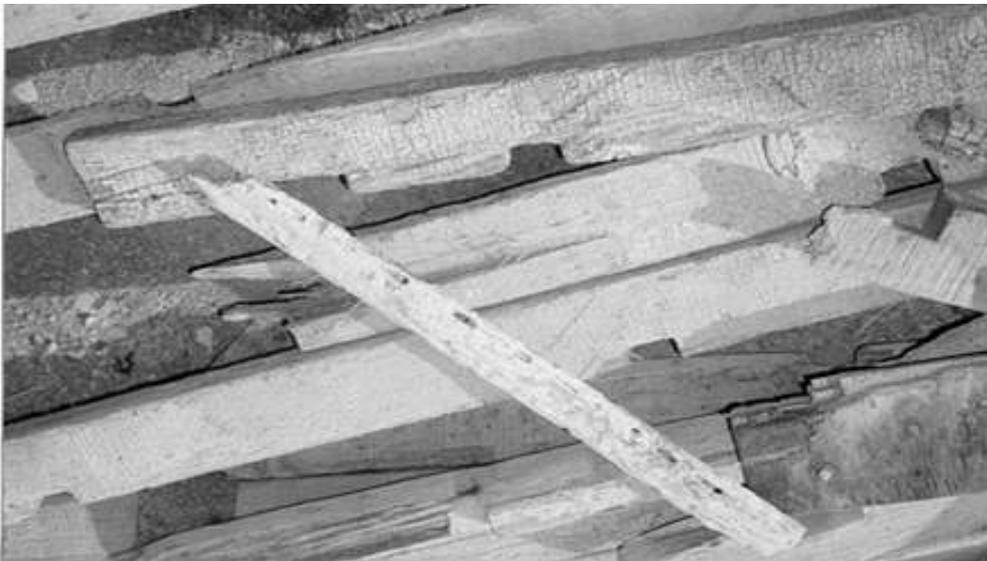
These wood rot primarily consume carbohydrates, i.e. cellulose and hemicellulose. Lignin is not much affected. Brown rotted wood changes to a brownish residue.



Decayed by Brown Rot

Soft Rot

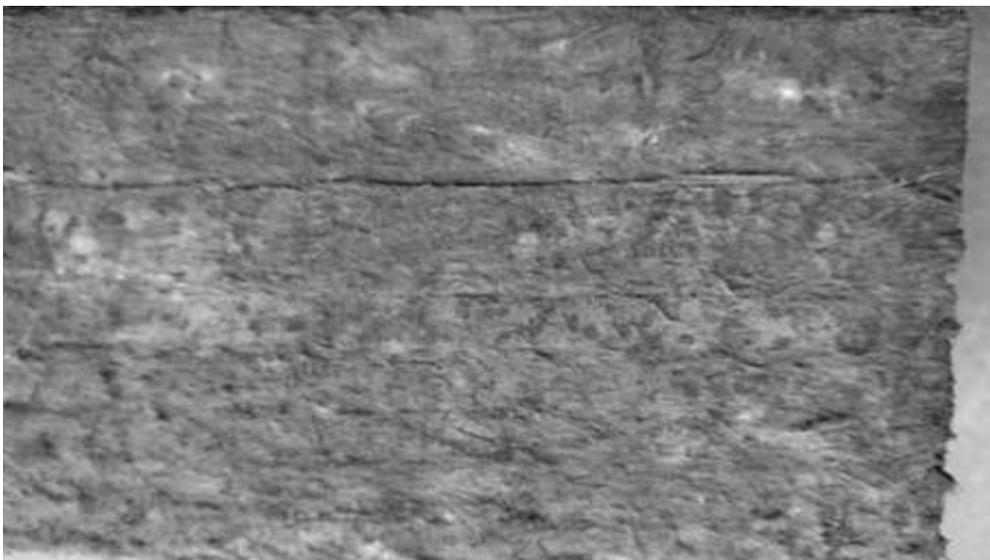
These fungi are different from those causing white rot and brown rot. Wood is attacked on surfaces exposed to high humidity or in contact with moist soil. The surface is eroded and weathered away. Such fungi have optimum growth in acidic (pH 6-7) conditions, while some can grow in alkaline conditions (pH 7-8) at which growth of most decay fungi is inhibited. The surface develops checks.



Decayed by Soft Rot

Molds

Fungi are observed as green, yellow, brown or black fuzzy or powdery surface growth on the wood. Freshly cut or seasoned plank during warm and humid weather conditions may be remarkably discolored within a short time. Although brushing or planing will remove the stain, these fungi can increase moisture absorbing ability of wood, thereby increasing the susceptibility of attack by decaying fungi.



Mold on Wood Sample

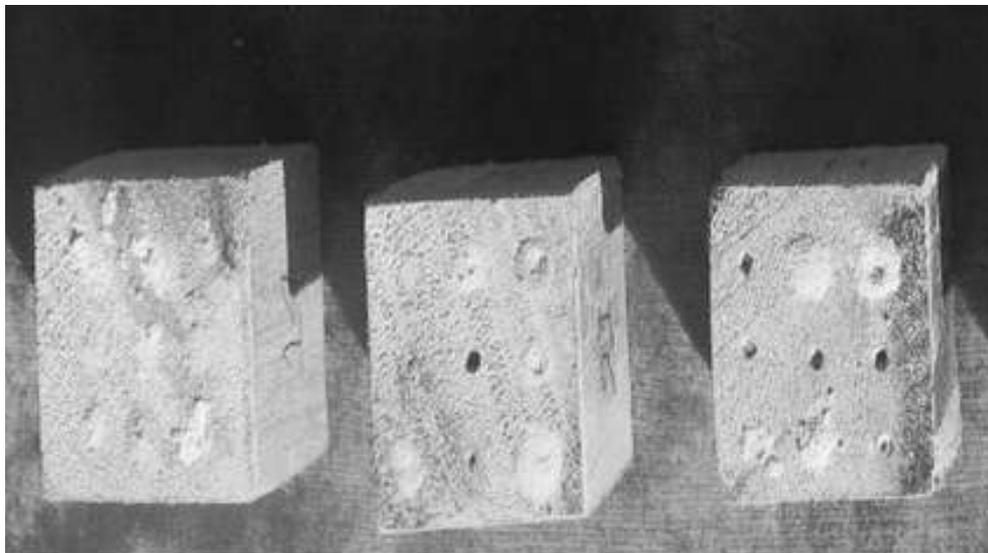


WOOD INFESTING AND DAMAGING INSECTS

Wood damaging pests and insects can attack antiques and building structures and cause heavy damage. They are mainly pinhole borers or shot hole borers: The attack is largely influenced by the changing moisture content and nutritional content in the timber. Pin-hole and shot-hole borers (Platypodidae and Scolytidae) are the first to appear on the scene and inflict severe damage. These borers are bark beetles (Scolytidae family) or ambrosia beetles (Scolytidae and Platypodidae). The degradation of round timber as well as sawn timber is enormous and is caused by borer holes as well as the black stains caused by the fungus. Ambrosia beetles of the family Platypodidae are more destructive as their tunnels are more extensive and extend deep into the heartwood also.

Powder Post Beetles

As drying of logs advances, false powder post beetles of the family Bostrichidae and true powder post beetles belonging to *Lyctus* spp. and *Stromatum barbatum* attack the relatively dry timber. Larvae of many false powder post beetle spp. bore in wood and cause typical powder post damage. The attack is mostly in sapwood of hardwoods, but some softwoods (conifers) are also attacked.



Powder Post Beetle infested experiential Wooden Blocks

Subterranean Termites

Termites use wood for both food and shelter. Nationally, termites are the most destructive wood-destroying insect. Subterranean termites can attack any unprotected wood or wood product. They live in and obtain their moisture from the soil. Although subterranean termites prefer the soil environment, they will build mud tubes over exposed surfaces from the soil to a food source. Subterranean termites live in large colonies that continually tunnel through soil searching for wood. Construction debris under a house is an excellent point of entry for these insects.

Dampwood termites live in the wood on which they feed and rely on the wood as a source of water; consequently, these termites attack only wood with a high moisture content. Once established, they can extend their activities into sound and dry wood. Damp wood termite workers are easily distinguished from subterranean termites by their large size and the presence of soldiers with very large heads.



Termite Colony and Wood Damaged by termites in field



3 WOOD PRESERVATION

NATURAL DURABILITY

Natural durability is the inherent resistance of wood to attack by wood-destroying organisms. Natural durability or decay resistance is defined as the ability of the heartwood of any wood species to resist decay. For practical purposes sapwood is always regarded as having low natural durability. Sapwood of all the wood species is a living part engaged in conducting the sap from root to crown and vice-versa and may contain starches which attract fungi and insects. This is lighter in colour and void of any extractives to lend durability. The inherited resistance is affected by temperature, amount of nutrients available for microorganisms, and the condition of the cell walls. The performance of wood in service depends on its resistance to biodeterioration. In the absence of natural resistance to degradation by micro-organisms, the wood needs to be treated with preservatives for long span of service life.

In practice, it is the heartwood that contains the chemicals (extractives) which have a toxic effect on wood-destroying organisms. The properties resulting from the presence of extractives in heart wood have been recognized for a long time. Heartwood is physiologically a dead portion of cells and does not take any active part in the life of the tree except to provide structural rigidity. Heartwood is more durable than sapwood due to the presence of some toxic chemicals. In some species, the heartwood is extremely durable. The inner most soft core is the pith and is also easily perishable. If the heartwood of any species is nondurable or moderately durable, preservative treatment becomes mandatory. Therefore, the efficient use of wood depends not only on the efficacy of the preservative used but also on the adequacy of treatment in terms of penetration and preservative loadings. BIS 401 describes the natural durability and preservatives efficacy testing in fields. Those species which have lower extractives do not perform satisfactorily in field and perishes fast. Therefore users have the option either use durable species like sal, sisoo, teak, deodar or use chemical to protect wood under service conditions.

CLASSIFICATION OF TIMBER ON THE BASIS OF NATURAL DURABILITY (IS: 401)

The durability depends on many factors viz. weather, soil and wood decaying insect and microbes. The durability class described is based on exterior testing of woods in stake size samples.

Non Durable	:	Class III	Life less than 60 months
Moderately Durable	:	Class II	Life between 60 to 120 months
Durable	:	Class I	Life more than 120 months

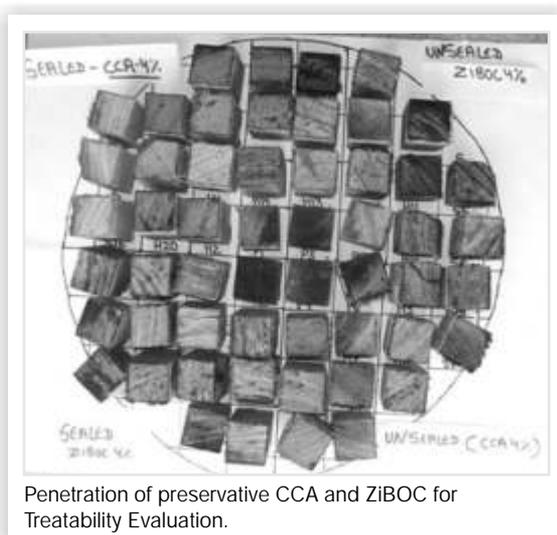


Natural Durability test of imported timber in field

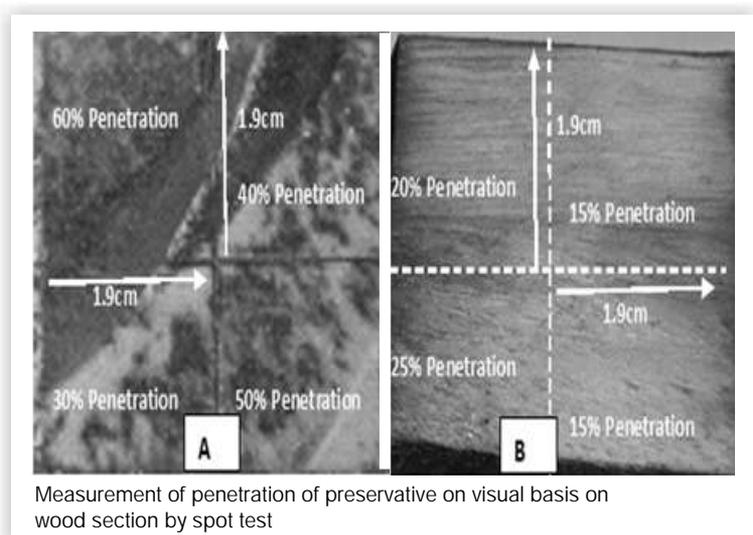
Treatability of Wood

Pressure impregnation of wood depends upon the micro-structure of wood subjected to treatment. This behaviour is depicted by treatability class. Most of the commercially available indigenous wood species have been tested and categorized into five treatability class 'a' to 'e' according to the ease of preservative impregnation. This classification is based on preservative absorption and penetration obtained by different preservatives and processes. These classes are defined below:

- Heartwood easily treatable.
- Heartwood treatable but complete penetration not always obtained in dimensions of over 6 cm.
- Heartwood only partially treatable.
- Heartwood refractory to treatment and
- Heartwood very refractory to treatment, penetration of preservative being practically nil even from the ends.



Penetration of preservative CCA and ZIBOC for Treatability Evaluation.



Measurement of penetration of preservative on visual basis on wood section by spot test



WOOD PROTECTION

- Short Term Protection
- Long Term Protection

CHOICE OF METHOD AND EQUIPMENT

Selection of suitable method and equipment is based on end use of commodity and hazard involved. As timber used in tropics, because of diverse climate, in buildings, would require protection against wood damaging termites while in cooling tower it needs protection against soft rot. Similarly in wooden bridges or marine applications of wood a preservative of non leachable type would be required. The efficacy of preservatives treatment depends on the chemical composition of the preservative, depth of penetration/impregnation and absorption. In depth impregnation would protect the wood in case of splits or cracks take place during service life. The amount of preservative required or retention of preservative to protect a unit volume of wood against any particular type of decay is called the toxic limit or the threshold value. This is usually used to compare the lethal effect of different preservatives and acts as a guide to retention required when treating wood.

CALCULATION OF PRESERVATIVE SOLUTION CONCENTRATION:

It is expressed as the weight of solid per unit volume of solution in percentage form. Thus 3 kg of salt dissolved in water to make 100 liters of solution will have strength

$$\text{Concentration} = \frac{3}{100} \times 100 = 3\%$$

CHANGE OF SOLUTION STRENGTH

EXAMPLE-1: The following example shows how solution strength can be reduced :

If it is required to change 200 liters of 5% solution to 2% solution strength calculate the weight of salt in the 200 litres of solution

Weight of salt = Solution strength x Volume

$$= \frac{5}{100} \times 200 = 10 \text{ kg}$$

This is the amount of salt in the 200 litres of the solution.

Then calculate the volume of water required to make up a solution of 2% strength with 10 kg of salt.

$$\text{Volume} = \frac{\text{Weight of salt}}{\text{Solution strength}}$$

$$= \frac{10 \times 100}{2} = 500 \text{ liters}$$

Therefore add 300 litres more water to the 200 litres of solution which already exist to make the required 500 litres.

EXAMPLE-2: The following example shows how to increase the solution strength :

It is required to increase the 400 litres of 5% solution to 8% solution

Calculate the amount of salt already in the solution

Amount of salt = Solution strength x Volume '

$$= \frac{5}{100} \times 400 = 20 \text{ kg}$$

Then calculate the amount of salt required to make 400 litres of 8% solution

$$\text{Weight of salt} = \frac{8}{100} \times 400 = 32 \text{ kg}$$

Therefore additional amount of salt required is $(32 - 20) = 12 \text{ kg}$

EVALUATION OF PRESERVATIVE RETENTION AND PENETRATION

Retention

Retention is the amount of salt retained in a unit volume of wood expressed in kg per cubic metre or lbs per cubic foot. This can be calculated for a charge (i.e. a parcel of timber which has been treated) or for individual pieces.

Example:

Volume of the total timber = 1.52m^3

Solution strength = 4%

Volume of preservative solution = 550 litres

Therefore weight of salt contained in the absorbed solution

= Solution Strength x Volume

$$= \frac{4}{100} \times 550 = 22 \text{ kg}$$

$$\text{Retention} = \frac{\text{Weight of Salt}}{\text{Volume of Timber}}$$

$$= \frac{22}{1.52} = 14.5 \text{ kg/m}^3$$



4 PREPARATIONS BEFORE WOOD TREATMENT

In order to get best treatment results, it is essential to prepare the material for treatment. If the timber is green, penetration of preservative is not possible by any pressure method. Diffusion, Osmose treatment and Boucherie method is applicable to green wood and the latter to green pole and bamboos, where bark and branches are to be retained. For all commercial treatment the timber after felling requires the following operations prior to treatment.

REMOVAL OF BARK FROM LOG i.e. DEBARKING

The removal of bark is essential because it carries wood boring insects and facilitates decay. Because of thickness it retards seasoning and resists the impregnation of preservative in the material.

PREPROCESSING i.e. PREDRYING

The presence of any free water in the timber retards the penetration of preservative liquid, it is therefore necessary to remove it prior to treatment. Predrying may be carried out by any recommended process, either air drying or any other seasoning process.

MACHINING OPERATIONS BEFORE PRESERVATIVE TREATMENT

Wood preservative treatments do not always penetrate all the way to the center of the wood. As a result, cutting into treated wood can expose untreated wood to wood-destroying organisms and reduce the service life of the wood product. Hence, it is preferable to perform all machining, including cutting to length, boring holes for fasteners, and framing, before the wood is treated. All machining operations, planning, shaping, mortising, boring etc. should preferably be done prior to treatment otherwise untreated portions will be exposed to the decay agencies in service conditions and in addition to this the chemical will go waste during the machining operations. Such operations are usually carried out after treating and drying to adequate moisture content. It is reported that treatment with water borne preservative results absorption of solution which causes distortion in shape after drying.

INCISING PRACTICE FOR REFRACTORY TIMBER

Some timber species are refractory to preservative treatment. In case of such timber, of large dimensions, it is essential to have treated shell all around. This is achieved by incising process. Incising makes a series of narrow holes or slits in wood. Incising prior to treatment improves preservative penetration. In incising, shallow slit like holes are made on the surface along the grain direction. Incising works along the grain as preservatives usually penetrate wood better along the grain than across it.

5 PROTECTION OF LOGS IN OUTSIDE STORAGE USING PROPHYLACTIC TREATMENT

Such storage should be carried out after debarking, as prophylactic treatments on unbarked logs are not only less effective but also more expensive. Following compositions are effective against insects. Cashew nut shell liquid (50:50 or 25:75) in kerosene is used to protect freshly felled timber against insects. Prophylactic treatments using chlorinated hydrocarbons like- BHC (Lindane), Aldrin, etc. Mixture of dieldrin with pentachlorophenol, BHC and pentachlorophenol and aldrin or dieldrin in kerosene oil are also used for production. Borax: boric acids and Sodium chrolopentaphenate (1:1:0.5%) are very effective against sap stain and moulds.



Prophylactic Treatment through Spray



6 PRESERVATION WITH CHEMICALS

The efficacy of any preservative treatment depends on the nature of preservative, retention and depth of impregnation, chemical formulation, application method, the amount of sapwood to heartwood, the moisture content of the wood and the distribution of the chemical in the wood. Generally Soft woods are easily and more uniformly treatable than hardwoods. Similarly sapwood is easily treatable than heartwood.

DESIRED CHARACTERISTICS OF A WOOD PRESERVATIVE

- High toxicity (high lethal effect even in low concentration) against wood decaying biological agencies and should not affect strength of wood
- High permanency and stability under all service conditions.
- High penetrability and impregnation throughout the entire cross section of the wood.
- Economical, easy to transport, should not increase unduly the inflammability of wood
- Easy to make and apply
- Safe to workers and consumers
- Should allow treated timber to be painted over or varnished.

7 PRESERVATIVES TYPES

TYPE-1: OIL BORNE PRESERVATIVES

Coal tar creosote is an oil type preservative. Coal tar and creosote available from coal is a dark brown viscous liquid. It, however, lends a dark brown colour to wood and freshly treated wood gives an unpleasant odour. It is usually used in admixture with fuel oil, which has no toxicity. The creosote for preservation purposes should conform to IS: 218-1961. 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. Its use is restricted to exterior applications, especially in contact with mud/ ground, wooden shingles, marine timbers, wooden poles etc. It is non corrosive, high permanence, offers good protection against termites but has unpleasant odour and treated material is difficult to be painted.



Shingle Treatment with Creosote in WP Plant, FRI



Creosote Treated Shingle



TYPE-2: ORGANIC SOLVENT SYSTEM TYPE PRESERVATIVE

Solvent type preservatives consist of active chemicals which are toxic to decaying agents and soluble in an organic solvents such as a petroleum distillate. These are slightly more expensive preservatives where the organic solvent acts as a carrier for toxic molecules and are available commercially in ready-to-use forms. A good formulation is an appropriate mixture of chemical constituents having fungicidal and insecticidal properties. There is little change of colour of the treated material but a residual odour may remain for some time. They are different from creosote, which needs no solvent. These formulations were developed for treating joinery timbers. They have a high degree of penetrability and can be applied under low vacuum or even by dipping only. Many new generation insecticides have recently come in the market. Cypermethrin and deltamethrin have shown efficacy against termites and have been recommended in formulations containing pentachlorophenol. The preservative are permanent and treated material is clean to handle and can be painted. Common examples: Trichlorophenol (TCP) and Copper/Zinc naphthenates (metallic soaps), Copper and zinc abietates, Lindane/ cypermethrin, chlorpyrifos etc.

COPPER NAPHTHENATE (OIL BORNE)

Copper naphthenate is made by reacting copper salts with naphthenic acid (a petroleum by-product). It is a viscous, dark blue-green liquid, soluble in petroleum solvents and should contain 6–8% copper by weight. It can be produced in a form emulsifiable in water, but is normally dissolved in heavy or light petroleum. The product is a good as wood preservative for preventing decay, and is suitable for ground contact. It's also safe to use near growing plants (after any volatile solvent used has evaporated). Treated wood has a distinctive green color, but this fades in sunlight. It is used for greenhouse lumber, yard and landscape timbers and seed and mushroom boxes. Disadvantages are its fairly high cost, lack of protection against termites, persistent "oily" smell and poor ability to take paint or glue. Organic solvent versions are flammable.

ZINC NAPHTHENATE (VOLATILE PETROLEUM OIL BORNE)

Zinc naphthenate is similar to copper naphthenate but is not an effective fungicide. It should only be used for above-ground products. The zinc salt does have the advantage of being almost colorless.

ADVANTAGES OF SOLVENT TYPE PRESERVATIVES

- Treated wood is clean.
- Penetrate well into timber.
- Do not leach out.
- Treated timber can be painted and glued easily.
- Do not cause swelling or distortion of the wood.
- Useful in remedial treatment of wood in buildings which have been attacked by insects or fungi as they are easily absorbed by most building timbers when applied by brush or spray.

DISADVANTAGES OF SOLVENT TYPE PRESERVATIVES

- Solvent type preservatives are relatively very expensive.
- Increase the flammability of the wood for a short time after the preservative has been applied.

8 TYPE- 3: WATER BORNE TYPE PRESERVATIVES

LEACHABLE TYPE

Water-soluble salts are dissolved in water. On treatment, the water evaporates leaving the salts inside the wood. These are leachable solutions and their use is restricted under cover. Wood material treated with these preservatives should not be exposed to rain or ground contact. These are generally odourless, and involve little fire hazard. Material treated with these preservatives can be painted or varnished or waxed, when dry. Boric acid and Borax have been used successfully against Lyctus borers, sapstain and some species of termites and are especially suitable for protecting veneers, plywood and packing case timbers for tea chests and for packing edible articles. They are also used as glue line protectants. Common example: Boric acid: Borax & copper sulphate, Sodium Pentachlorophenate, Sodium Fluoride, chlopyriphos.

Boron Based Formulations

Boron compounds are applied by high-pressure processes to seasoned timber or by diffusion processes to timber before seasoning. Such treatments do not change the colour of the timber. Treatment may raise the grain and, if applied using vacuum-high pressure process, cause the timber to swell and cause some distortion. It may be applied by brush coating also. These are highly toxic to all types of organisms encountered in building timbers and form very good preservatives for wood and wood panel products such as plywood, because of their penetrating property.

Zinc Chloride

It is quite toxic to fungi and insects but not so toxic to termites. It has fire retardant properties also. Wood treated with this tends to be hygroscopic, which may interfere with paint films.

Sodium Pentachlorophenate (NaPCP)

Water soluble salt of pentachlorophenol is highly effective against sap stain.

FIXED TYPE

Forest Research Institute has given to the world today's two best known wood preservatives i.e. Copper-chrome-arsenic (CCA) known as Ascu and Copper-chrome-boron (CCB). These preservatives consist of mixture of various salts having broad-spectrum efficacy against a variety of organisms and a fixative salt, usually sodium or potassium dichromate. It is necessary that the treated material be allowed to dry for 2 to 3 weeks to complete the fixation process. These preservatives shall be applied cold; as these are liable to get precipitated when heated, particularly in the presence of reducing substance in timber. These formulations are proportionate mixtures of different salts which interact with each other in the presence of bamboo/wood and become chemically fixed. The inorganic arsenicals (also called the waterborne preservatives) are a group of preservatives that include chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), ammoniacal copper zinc arsenate (ACZA), chromated zinc chloride (CZC) and acid copper chromate (ACC). Timber treated with these preservatives may be used outdoors and can also be painted.

A new enviro-safe waterborne and fixed composition of three salts i.e. ZiBOC has been developed in FRI Dehardun and tested in field for approximately ten years in bamboo and wood. Results revealed its efficacy comparable to CCA. Treatment of plantation species with ZiBOC justifies the necessity of treatment of nondurable species for long lifespan products and also suggests an alternative to toxic preservatives. No specific requirement for the treatment with ZiBOC is required. All procedures opted for CCA are same in ZiBOC also. All routine treatment methods opted for water borne preservatives were followed with ZiBOC in bamboo and wood treatment. Tested for exterior applications at various locations, under shade interiors, cooling towers and bamboos (Patent No. 257393 awarded on 28.09.2013).



- Copper-Chrome-Arsenic Composition (CCA) is especially recommended in heavy termite and marine borer infested areas and in cooling tower timbers where soft rot is the chief deteriorating agency.
- Acid Cupric-Chromate Composition (ACC) is basically effective against fungi and recommended for interior use (out of ground contact) in areas with no termite hazards.
- Copper-Chrome-Boron Composition (CCB) is recommended for general use, including timber in cooling tower.
- Zinc-meta-Arsenite consisting arsenic trioxide and zinc oxide (ZnO) in the ratio of 3:2, and acetic acid just sufficient to keep zinc-meta-arsenite in solution under operating conditions.

Advantages of Water Borne Preservatives

These preservatives can be transported in solid or concentrated form. They are to be used with the cheapest of all solvents water. They are very effective against both fungi and insects. They leave the wood in a clean condition which is not unpleasant to handle. The treated wood can be painted and glued once the water has dried off. They can readily be combined with fire retardant chemicals.

Disadvantages of Water-Borne Preservatives

Most of these salts are poisonous though the dried treated wood is usually safe to handle. When applied to seasoned timber, it re-wets the wood, causes it to swell and has to be re-dried again at room temperature.

COMPOSITION OF PRESERVATIVES MOST COMMONLY USED IN INDUSTRY

Exterior uses and cooling tower industry.

Copper-Chrome-Arsenic composition (CCA)

This preservative known as ASCU was developed at F.R.I. (Kamesam 1933) and is today's best broad spectrum wood preservative in wide use. The basic formulation is a uniform and homogenous mixture of the above salts reacted together at controlled temperatures consisting of following percentage (by weight) (IS:10013 Part II) (Anon., 1980).

Copper sulphate ($CuSO_4 \cdot 5H_2O$)	37.5
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	
or	
Potassium dichromate ($K_2Cr_2O_7$)	50.0
Arsenic pentoxide ($As_2O_5 \cdot 2H_2O$)	12.5
Total solid content should be more than 95 percent	

Copper-Chrome-Boric Compositions

This preservative was also developed by F.R.I. in 1941-42 (Kamesam, 1943) to substitute costly arsenic by boron. The composition is effective at slightly higher doses because of leachable nature of boric acid. (IS: 10013 Part III-1981).

Copper sulphate ($CuSO_4 \cdot 5H_2O$)	3 parts
Boric acid (H_3BO_3)	1.5 parts
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	
or	4 parts
Potassium dichromate ($K_2Cr_2O_7$)	

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 known manufacturers.
- To prepare a solution of any concentration, the weight of the quantity to be dissolved can be found out by the given method and formula.

EXAMPLE: To prepare 8% CCA solution where the strength/ concentration of CCA is 95 and the required volume is 100 litres.

$$Q = (C \times V) / S.$$

Where

Q = Quantity to be dissolved in water

C = Concentration of solution required

V = Volume of solution to be prepared

S = Concentration of salt/paste

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

- Same process will be followed for Boric: Borax solution: Boric acid and Borax are usually mixed in the ratio of 50:50.
- 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
50:50 ratio	5 kg	5 kg	100 litres

Boron salts may be heated to about 50 0C while making solutions or during treatment to hasten the process.



9 METHODS OF APPLICATION OF PRESERVATIVE IN WOOD TREATMENT

NON PRESSURE PROCESSES

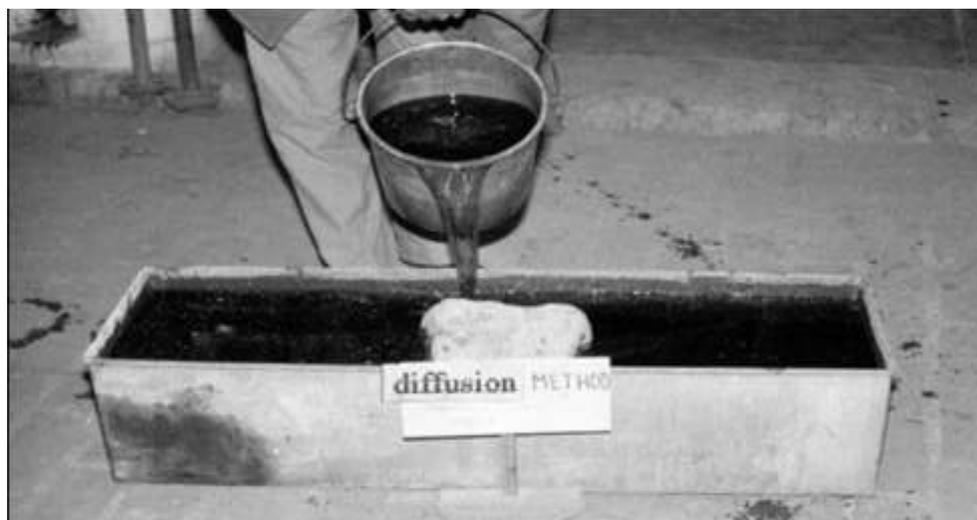
Non-pressure processes are useful especially when slight protection of the wood is required. However, in cases where the penetration and retention are comparable to pressure treatment, the level of protection should be the same.

Surface Application: (Brushing, Spraying, and Pouring)

This is done by brushing, spraying or dipping in the preservative solution for a short period. For this treatment, timber (if it is round) is debarked thoroughly. Penetration and retention are minimal, and any abrasions can expose untreated wood to pests. Brushing, spraying, and pouring are most widely used for protecting areas of treated wood that have been cut or machined, such as when using treated wood in a construction project, thereby exposing untreated surfaces. For the oil type of preservatives, the moisture content in the material shall not be more than 20 percent, with aqueous solutions, moisture content of 20 to 30 percent is permissible. At least two coats should be applied; the second and subsequent coats are to be applied after the first has dried or soaked into the wood. It has a limited scope and is used mostly for treating material at site and for retreatment of cut surfaces. This may be repeated periodically.

Dipping Treatment

The debarked material submerged in the preservative solution for a sufficiently long period until the required absorption of the preservative is obtained. Green wood that has recently been felled (e.g., poles) is often dipped at sawmills to protect it from sapstain fungi until it can be properly dried. Because protection is provided for only a short time, the wood should be dried as soon as possible after dipping. Normally, soaking of veneers in the preservative solution for a period of 1 to 2 min is adequate for thickness up to 1.8 mm in the case of refractory species and up to 3 mm for other species. Prefinished joinery/furniture components/items can also be treated with light organic solvent type wood preservatives by this process. Bamboo can be treated within a week in split form in all water born preservatives described above.



Water Borne Preservative Treatment by Diffusion Process



Bamboo Treatment by Dipping Process

Diffusion Process

The diffusion process provides a way to impregnate green or wet wood with waterborne preservatives like CCA, CCB and Borax: boric acid. The wood is soaked in a preservative solution for an estimated time. The preservative then moves from the solution or paste into the moist regions in the wood by diffusion, which is movement of a chemical from an area of higher concentration to an area of lower concentration. It is applied to bamboo, wood and thatch. Time of diffusion depends on material and thickness.



Thatch Treatment by Dip Diffusion Process

HOT AND COLD PROCESS

The timber is submerged in the oil borne preservative or solution, which is then heated to about 90°C and maintained at this temperature for a 2-3 hrs, allowed to cool until the required absorption of preservative is obtained. Creosote treatments are given by this method.



Hot and Cold Process of Shingles Treatment at WP FRI.

BOUCHERIE PROCESS

Treatment of sapwood of almost all green round poles, soon after felling with the bark on it may be carried out by using any of the inorganic water soluble preservatives. The treatment is carried out by attaching to the butt end of a pole, a rubber hose connected to a reservoir containing the water borne preservative solution. If an air pressure of 1 to 2 kg/cm² is applied on the surface of the preservative in the reservoir, the reservoir need not be raised high above the ground and the treatment can be hastened to an appreciable extent. Pressure up to 5 kg/cm² may be used for treatment of green poles with specially designed pressure caps. The treatment is stopped when the concentration of preservative in the drip is nearly the same as that of the solution in the reservoir.



Bamboo Treatment by Boucherie Process

PRESSURE AND VACUUM PROCESS

Pressure process may be employed with any type of preservative. In the case of oil type preservative, a temperature of 80 to 90°C shall be maintained during the pressure period. The wood planks or bamboo in solid or split form is introduced into the cylinder. In the case of thin planks and plywood, spacers or grills should be used to separate the pieces. The door is tightly closed and then a vacuum of at least 56 cm of mercury is created and maintained for half an hour. At the end of the vacuum period, the preservative is introduced into the cylinder, with the vacuum pump working. When the cylinder is filled with the preservative, vacuum pump is stopped and the cylinder is subjected to an antiseptic pressure of 3.5 to 12.5 kg/cm², depending on the species, size, refractory nature of the material, etc. This injects preservative into the timber. The pressure is held until the desired absorption is obtained, after which the preservative is withdrawn from the cylinder and finally a vacuum of 38 to 56 cm of mercury for about 15 min is applied once again to free the material from the dripping preservative. The amount of pressure and vacuum applied and also their periods of application vary with the species, the retention required, the thickness converted material etc.



(a)

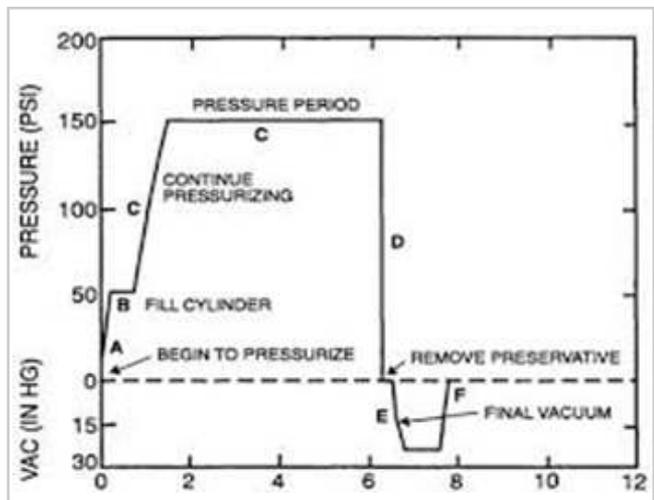


(b)

Wood and Bamboo Treatment by Pressure and Vacuum Process in WP, FRI



(a)



(b)

Operation and Schedule of Treatment in Vacuum-Pressure Plant



The main steps in the Full Cell Process are :

- Preliminary vacuum period
- Fill cylinder with preservative
- Build up pressure
- Maximum pressure held
- Release pressure
- Empty cylinder of preservative
- Final vacuum period
- Release vacuum
- Unloading of material, leave for 1-3 weeks for fixation of preservative and drying of wood material.

Types of Pressure Process :

The method opted depends on the species and end use for commodity

- The Full Cell Process
- The Empty Cell Processes
- Oscillating Pressure Process
- Low Pressure Processes

Choice of Preservative Treatment:

The choice of treatment is governed by the timber to be treated, its sapwood content and the use to which it is put to. The net absorption of the preservative in the timber shall be determined by chemical analysis; the net absorption of oils shall be expressed as kilograms per cubic metre in the case of salts, weights of dry chemicals in kilograms including the water of crystallization per cubic meter, shall be given.

METHOD FOR THE PENETRATION CHECK OF PRESERVATIVE IN WOOD SAMPLES

Lack of sufficient loading/distribution of chemicals within the wood / bamboo structure is usually responsible for early failure in use. While penetration and distribution of conventional preservatives can be easily done anywhere by qualitative testing, the amount of preservative loaded in the bamboo can be checked only by quantitative estimations. To check the penetration/distribution of preservatives, the sample 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 as follows.

Copper Based Formulations

COPPER-CHROME ARSENIC composition, ACID-CUPRIC-CHROMATE composition, BORATED-COPPER-CHROME-ARSENIC composition and AMMONIACAL-COPPER-ARSENITE composition.

- Detection for Copper
Dissolve 0.5 g chrome Azurol-S and 5.0 g of sodium acetate in 80 ml water and dilute to 100 ml. Spray the solution over split section or boring with a fine sprayer on the cut surface of treated wood. A deep blue colour shows the presence of copper.

- Detection for Chromium

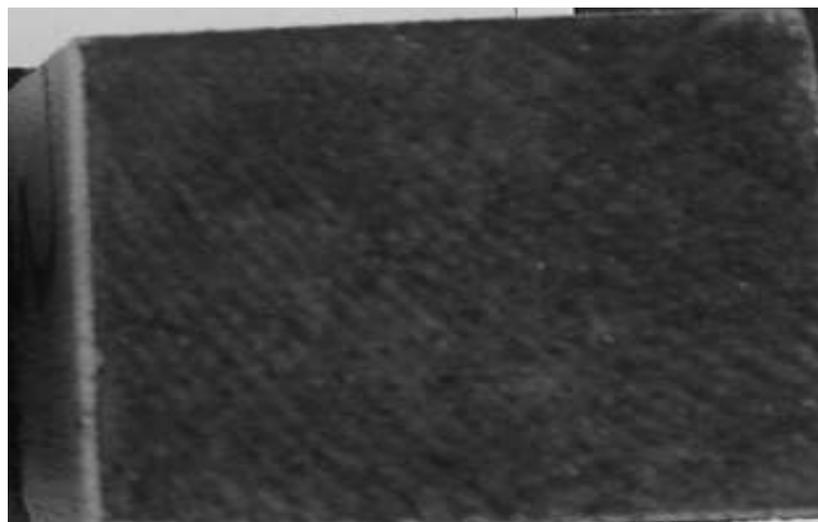
Dissolve 0.5 g diphenyl carbazide in 50 ml isopropyl alcohol and 50 ml of distilled water. Spray the solution on the boring or cross section of treated wood. Portions containing chromium will develop a purple colour while non penetrated portion will remain as such.

- Detection for Arsenic

- Solution 1 - 3.5 g ammonium molybdate dissolved in 90 ml distilled water followed by 9 ml concentrated nitric acid.
- Solution 2- 0.7 g benzidine dihydrochloride dissolved in 10 ml concentrated acetic acid and diluted to 100ml by adding 90 ml distilled water
- Solution 3 - 30g stannous chloride dissolved in 100 ml 1 : 1 hydrochloric acid in distilled water.

Solution 1 may be prepared fresh for each day testing. Solution 2 and Solution 3 may be stored in clean glass with stopper in brown glass bottles for one week.

Apply solution 1 to the boring or cross section ensuring that entire wood surface is saturated. Solution 2 is next applied in the same way as Solution 1. Solution 3 is last applied by pouring over the cross section or boring beginning at untreated part. The entire wood surface will immediately turn bluish.



Complete Impregnation of Copper Based Preservative

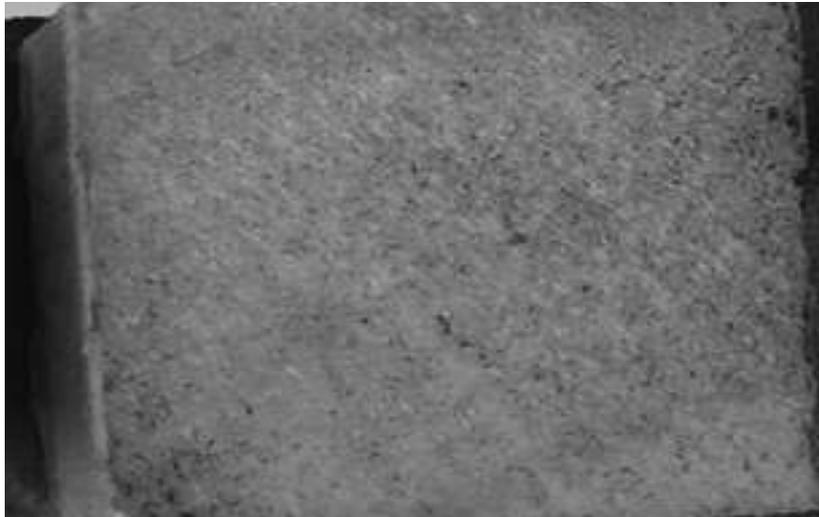
Boron Based Preservatives:

Method for the detection of Boron in Borax: Boric Acid, CCB: and other boron based preservatives.

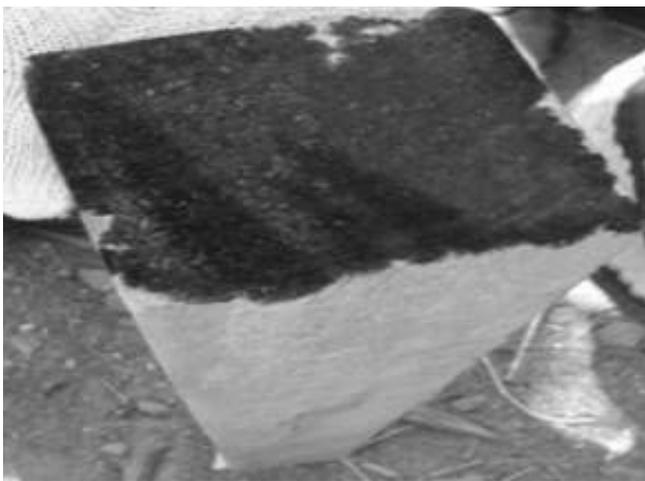
- Solution 1: Extract 10 g turmeric powder with 90 g ethyl alcohol. Decant or filter to obtain clear solution.
- Solution 2: 20 ml of concentrated hydrochloric acid diluted to 100 ml with ethyl alcohol and then saturated with salicylic acid (about 13 g per 100 ml).



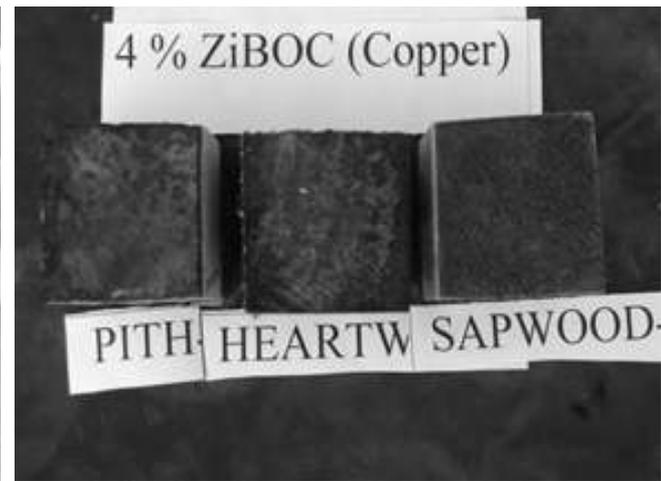
Solution 1 is applied on the dry surface of wood by spraying or with a dropper and the surface is allowed to dry for a few minutes. Solution 2 is then applied in a similar manner to the areas that have been coloured yellow by the application of Solution 1. The colour changes shall be observed carefully, areas having presence of boron turn red.



Complete Impregnation of Boron Based Preservative



Improper Impregnation



Preservative Impregnation in Wood

Cross Cut Section exhibiting preservative presence by qualitative test

10 PROTECTING HUMAN HEALTH AND THE ENVIRONMENT

PRECAUTIONS FOR PLANT OPERATORS/WORKERS

Anyone working with wood preservatives is exposed to these chemicals to some extent, but the exposure can be minimized by following the directions on the preservative label and by developing good work habits. It is the responsibility of the manager supervisor/plant incharge of any wood preserving operation to ensure that proper handling procedures, protective clothing, and safety equipment are provided to workers in order to protect their health and conform to label instructions

Precautions while working with Creosotes

- Creosote penetrates deeply into and remains for a long time. Exposure to creosote may present certain hazards; therefore, the following precautions should be taken.
- Wood treated with creosote should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture)
- Should not be used in residential interiors & Creosote-treated wood in interiors of industrial buildings should be used only for industrial building components that are in ground contact and are subject to decay or insect infestation and wood block flooring.
- Creosote-treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges.

Precautions while working with Inorganic Arsenicals

Inorganic arsenic penetrates deeply into and remains in the pressure-treated wood for a long time. Exposure to inorganic arsenic may pose certain hazards;

- Do not use treated wood under circumstances where the preservative may become a component of food or animal feed.
- Treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges.
- Handling precautions, dispose of treated wood by ordinary trash collection or burial.
- Treated wood should not be burned in open fires or in stoves, fireplaces or residential boilers because toxic chemicals may be produced as part of the smoke and ashes.

Do's and Don'ts

- 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 should be permitted.
- 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
- Preservative treatment plant area should be separated than other working labs
- If working in plant, wash hands often, especially before using the restroom or eating.
- Launder protective clothing like aprons, dangri at the work site.
- Sometimes wood workers enter into treatment cylinders to arrange small sections like shingles those who enter pressure-treatment cylinders or other related equipment contaminated with wood-treatment solutions must wear protective accessories that is impervious to wood treatment solutions.
- The pesticide label given on the packing's will specify the type of personal protective equipment and clothing that should be worn when working with wood preservatives.
- Where skin contact is expected like, when handling freshly treated wood or manually opening pressure-treatment cylinders, the label will state the use of impermeable gloves.
- Wood treated with inorganic arsenic should be used only for exterior uses.
- Inorganic arsenic penetrates deeply into and remains in the pressure-treated wood for a long time hence burning of wood or recycling to other products should be avoided.
- Sawing of inorganic arsenic treated wood should be avoided or done under supervision as dust produced may have harmful effect, use of goggles and dust mask is mandatory.
- Store chemicals in a dry, well-ventilated, locked area, in well-sealed containers, protect liquid storage against tank break.

DISPOSAL OF PRESERVATIVE AFTER TREATMENT

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

FIRST AID

- Since accidents do happen, first aid information on the chemical(s) in use must be readily available.
- Inhalation: Move to fresh air. If breathing is difficult, give oxygen. Get medical attention immediately.
- Some species may cause allergic respiratory reactions with asthma-like symptoms in sensitized individuals, seek medical assistance.
- Remove contaminated clothing, if it is contact with skin
- Wash skin thoroughly with soap and water for several minutes.

- Prolonged contact with treated wood and/or treated wood dust, especially when freshly treated at the plant, may cause irritation to the skin, seek medical help.
- Rough handling or rubbing of the treated wood may increase skin irritation avoid it.
- Do not rub eye. In case of eye irritation immediately flush eye(s) with plenty of water. Remove any contact lenses and open eyelids wide apart. If eye irritation persists:, get medical advice/attention dust is ingested. Get medical attention if any discomfort continues. In case of Ingestion rinse mouth thoroughly if
- Most important symptoms/effects, acute and delayed wood dust, it cause nasal dryness, irritation and mucostasis. Coughing, wheezing, sneezing, sinusitis and prolonged colds hence medical advice is necessary.

DISPLAY NOTICE BOARDS IN PLANT AREA

- List sources of personal protective equipment requirements.
- Indicate conditions under which worker must wear a respirator.
- Give examples of how you can detect a problem with a pump, valve, filter, or line.
- Give reasons why you benefit from reducing the amount of waste your facility generates.
- Give examples of how you can reduce the amount of waste your facility generates.
- Describe proper procedures for storage and disposal of solid and hazardous wastes, including satellite accumulation of hazardous waste.
- Explain the need for emergency planning.
- Clearly mention that when and to whom you need to report a spill.
- Give examples of how you can prevent spills.
- Describe ways to clean up and reclaim discharges of preservative within a facility's containment area.

POTENTIAL SUPPLIERS OF PLANT AND PRESERVATIVE

- R. D. Industrial Corporation , Mr. Ashish Bubna, 88, Manicktata Road, Kolkata, Phone 09821591099
- Dattashri Enterprises, Khadakwasla, Pune, Maharashtra
- Aadinath Chemical Industries Office: Flat No. 5, Nirmal Sadan, Kasturba Cross Road No. 1, Borivali (East) Mumbai-400 066, Maharashtra, India Tele Ph. + (91)-(22)-32604418 Tele Fax : + (91)-(22)-28544417
- ASCU Arch Timber Protection Limited , O.P. Khenka, P-46,A, Radha Bazar Line, 4th Floor, Radha Bazar, Kolkata - 700020 Weat Bengal, India

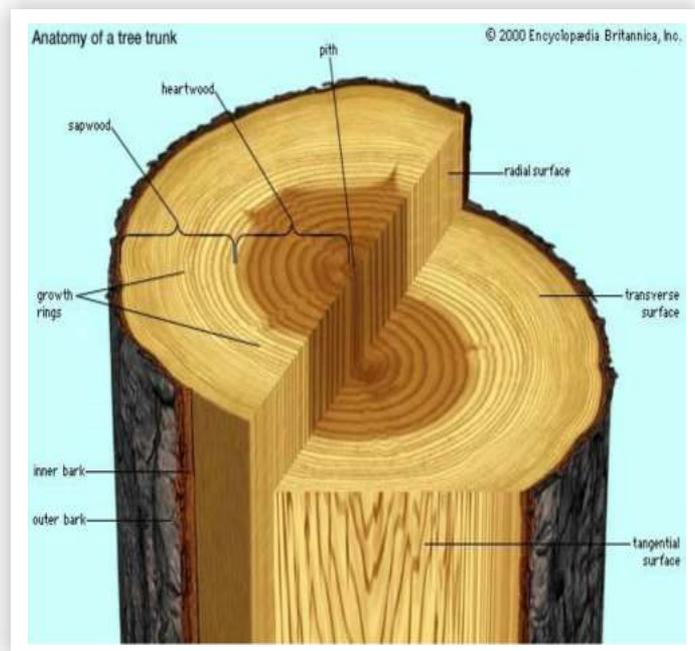


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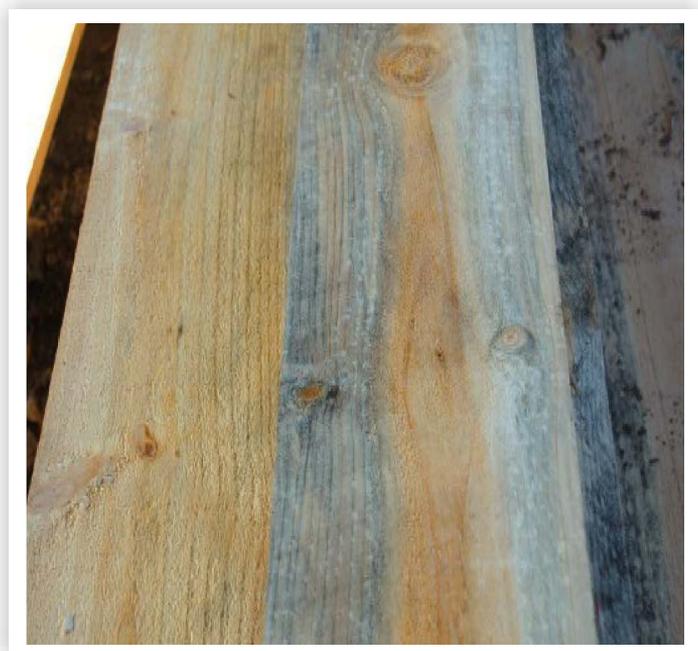


Demonstration structure made of ZiBOC treated bamboo and thatch 2008



Anatomy of tree trunk

Source <https://www.britannica.com/science/wood-plant-tissue/Wood-as-a-material/media/647253/55252>



Sapstain on freshly converted wood plank



Natural durability test of imported timber in field



Penetration of preservative CCA and ZiBOC for treatability evaluation



Complete impregnation of copper based preservative



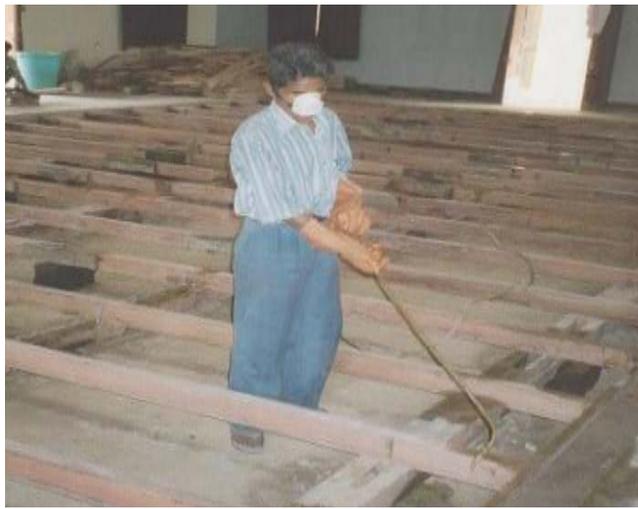
Complete impregnation of boron based preservative (Preservative impregnation in wood)



Bamboo treatment by pressure and vacuum process in WP, FRI



Operation and schedule of treatment in vacuum-pressure plant



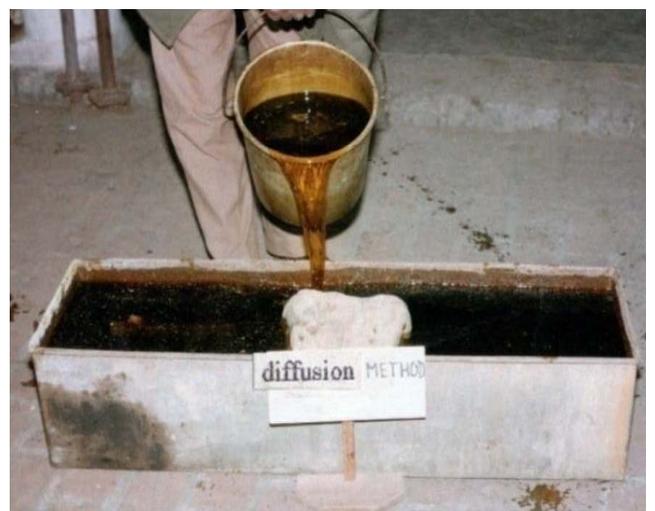
Prophylactic treatment through spray



Shingle treatment with creosote in WP Plant, FRI



Creosote treated shingle



Water borne preservative treatment by diffusion process



Bamboo treatment by dipping process



Thatch treatment by dip diffusion process



Hot and cold process of Shingles treatment at WP Plant, FRI



Bamboo treatment by boucherie process



Indian Council of Forestry Research & Education

(An autonomous body of Ministry of Environment, Forest & Climate Change,
Government of India)

New Forest, Dehradun - 248 006 (Uttarakhand)

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