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DETERMINATION OF PENETERATION AND RETENTION OF THREE BAMBOO SPECIES *(Dendrocalamus giganteus, Bambusa gigansula, Gigantochola andamanica)* WITH CCA-C PRESERVATIVE.

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Dedicated to…..

My beloved parents

Acknowledgement

All praises are to the Supreme Being creator,ruler of the universe, whose mercy keeps us alive and enables us to pursue my education in Forestry and Wood Technology Discipline, Life Science School, Khulna University, Khulna and to complete the project thesis for the degree of Bachelor of Science (Hon's) degree in Forestry. Then I like to express my gratitude to my parent.Without their continuous inspiration, the present achievement would not be possible.

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Declaration

The result submitted in this thesis are entirely the author's own investigations and no part of the results have not been accepted for any degree, nor it is being concurrently submitted for any degree.

Rabeya Khatun

ABSTRACT

Bamboos play a dominant role as woody raw material for a variety of products in the tropical regions. Bamboo is one of the strongest structural materials used in rural areas of developing countries. Moisture content of bamboo varies along its height location and with seasoning period, which affects treatment behavior of bamboo. It is one of the important factors in deciding the life of bamboo. This paper presents results of experimental investigations made to evaluate the penetration (%) and retention (kg/m³) of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula)and Kali(Gigantochola andamanica) with green and oven dry sample . In the present study moisture content, shrinkage, penetration and retention at different height location are worked out. The moisture content varies along the height for green bamboo or at any time after harvesting. The top portions had consistently lower moisture content than the middle or basal at all stages of seasoning. shrinkage on oven dry mass basis decreases from top to bottom.In this study, above mentioned three bamboo species were treated in a commercial wood-treating plant using a full-cell process with Chromated Copper Arsenate (CCA) preservative to target retentions of 20 kg/m^3. Results indicate that among three bamboo species oven dried Kali (Gigantochola andamanica) sample achieve approximately 94.27% of the target CCA penetration with 17.8 kg/m³ retention .

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Abbreviation

AWPA	American Wood Preservation Association
BREB	Bangladerh Rural Electrification Board
CCA	Chromated Copper Arsenate
Fig.	Figure
MC	Moisture Content
psi	pounds per square inch
PCP	pentachlorophenol

Chapter:1

1. INTRODUCTION

1.1 Background of the study:

Bamboos play a dominant role as woody raw material for a variety of products in the tropical regions. Almost all continents, except Europe, have indigenous bamboo species. Bamboos are, however, more abundant in the tropics, with over 75 genera and 1250 species, ranging from small grasses to giants of over 40 m in height and 0.3 m in diameter (Tewari, 1993). In South and Southeast Asia, the most economically important species for structural uses from the point of view of easy availability are Bambusa balcoa,*Bambusa* bambos, *Bambusa blumeana, Bambusa nutans, Bambusa polymorpha, Bambusa tulda, Barnbusa vulgaris, Dendrocalarmus hamiltonii, Dendrocalarmus strictus, Melocanna barnbusoides, Gigan tochloa spp., Ochlandra travanicorica and Oxytenathera nigroeiliata.* Bamboo is one of nature's most valuable gifts to mankind. Its remarkable growth rate and versatile properties have made it one of the most sought after materials, especially in tropical countries. Some of the characteristics of bamboo resemble those of wood. However, its growth characteristics and microstructure make it different from wood; hence the need for specialised techniques for deriving maximum advantage of its diversified uses. A major drawback with bamboo is that it is not durable against wood degrading organisms. Thus, most bamboos used for structural purposes in rural and tribal housing deteriorate in a couple of years, putting heavy pressure on the resource, owing to increased demands for frequent replacements. This adversely affects the supplies of bamboo, even in bamboo rich regions. Considerable research work has been carried out in bamboo producing countries in the Asian region, as a result of which the service life of bamboo can be increased. Without any protective treatment, most bamboo species have an average natural durability of less than 2 years. Stored under cover, untreated bamboo may last 4-7 years. These variations in bamboo durability strongly depend on the species, the length of the culm, the thickness of the wall, but also, and equally important, the time of harvesting. The lower portion of the bamboo culm is considered more durable, while the soft inner part of the wall deteriorates faster than the outer harder portion. This is related to the anatomical and chemical nature of the woody cells. Although some of the characteristics of bamboo resemble those of wood, its growth characteristics and microstructure is different. Unlike timber varieties like teak, the structure of bamboo is void of toxic deposits.The large amounts of starch present in bamboo makes it highly attractive to mold and fungi, termites and powder-post beetles. They cause much damage during

drying, storage, and subsequent use. Tests have also shown that bamboo is more prone to soft rot and white rot attack than to brown rot. Bamboo consists of 50-70% hemicellulose,30% pentosans, and 20-25% lignin. The lignin present in bamboos is unique, and undergoes changes during the growth of the culm. Bamboo is also known to be rich in silica (0.5 to 4%), but the entire silica is located in the outer layer (1 mm), with hardly any silica in the rest of the wall. Bamboos also have minor amounts of waxes, resins and tannins, but none of these have enough toxicity to improve its natural durability. Hence bamboo treatment is necessary for enhancing its durability .In this study penetration and retention of three bamboo species is assessed.

1.2 Objectives of the Study:

- To determine the shrinkage of bamboo.
- To determine the MC% of bamboo .
- To determine the penetration and retention of CCA treated bamboo.

Chapter:2

2. LITERATURE REVIEW :

2.1 Bamboo and its composition:

Bamboo is a tribe of flowering perennial evergreen plants in the grass family. Giant bamboos are the largest members of the grassfamily. Bamboo consists of 50-70% hemicellulose, 30% pentosans, and 20-25% lignin. The lignin present in bamboos is unique, and undergoes changes during the growth of the culm. Bamboo is also known to be rich in silica (0.5 to 4%), but the entire silica is located in the outer layer (1 mm), with hardly any silica in the rest of the wall. Bamboos also have minor amounts of waxes, resins and tannins, but none of these have enough toxicity to improve its natural durability. The word bamboo comes from the Kannada term bambu, which was introduced to English through Indonesian and Malay.

The structure of a bamboo culm transverse section is characterized by numerous vascular bundles. The size of the vascular bundle is large in the inner and middle layer but smaller and denser in the outer layer.

The fiber length was mainly between 1.6-3.1 mm. Older bamboo has more short fiber. So does outer layer compared to the middle and inner layer.

2.2 Bamboo Taxonomy and Classification

Bamboos have an unique anatomy and their superproductive behaviors are truly interesting to study. Bamboo is part of the true grass family, and makes up the largest and most productive member of the grass family. Over 1,000 species and 91 genera of bamboo exist throughout the world and they grow in a wide range of climates and regions. Bamboo has the ability to grow in regions that range from the sub-Sarahan deserts of Africa, to the cold mountain terrain of the Himalayas. It has a long and detailed history and is one of the most versatile plants in the world. The majority of species are native to the tropics of Asia, although one variety is native to the United States, Arundinaria gigantea. The sizes of bamboo species vary greatly. The smallest varieties grow to a height of 11 inches, while giant timber bamboo can reach heights of over 100 feet. Below is a list displaying the taxonomy under which bamboo is classified.

KINGDOM: Plantae

DIVISION: Magnoliophyta

CLASS: Liliopsida

SUBCLASS: Commelinidae

ORDER: Cyperales

FAMILY: Poaceaes

SUBFAMILY: Bambusoideae

TRIBE: Bambuseae

SUBTRIBE: bambusinae

It is also important to point out that bamboo is commonly distinguished by its root system as either running or clumping.Basically, running bamboos are invasive and spread rapidly, while clumping bamboos generally stay confined to a single area.

2.3 The Anatomy of a Bamboo Plant

This section deals with the morphology and physiology of the bamboo plant. Morphology refers to the outward appearance of the plant's components, while physiology refers to their biological function. We've done our best to merge these two distinctions to give you the overall idea of how bamboo works. Bamboo is structured beautifully and is unique from other plants and trees that share similar characteristics and features. The main components of a bamboo plant include rhizomes, roots, culms, branches, leaves, and flowers.

Rhizomes – Rhizomes are horizontal stems extending from the domain plant that travel underground with the objective of colonizing new territory. As rhizomes spread through the soil they collect and store the primary nutrients for growth. The storage of energy is the primary reason we see bamboo exhibit rapid and massive growth. This also gives bamboo plants the ability to utilize energy created from both photosynthesis and that which is stored in the rhizomes. Over time, the rhizomes will create an interconnected system of plants, all of which draw on the rhizomes for nutrients. For example, when a single bamboo plant has been introduced into an area, all other bamboo plants that emerge will belong to the same organism. In appearance, rhizomes are segmented and covered by a protective sheath. The leaves are reduced along the sheath, as they provide no photosynthetic benefit underground.

The sheath provides the plant with the protection needed to breach the surface to form a culm. A healthy rhizome is usually slightly yellow or ivory in color, although possible colors may include red, brown, green, and purple. The appearance and behavior of rhizomes differs among species, and is divided into two main categories which include the pachymorph system and the leptomorph system.

Fig-2.3.1: Leptomorph bamboo rhizome protruding from the soil.

The pachymorph rhizome system, which is found in clumping bamboos, expands horizontally only by short distances each year. The rhizomes are generally short and thick in appearance. They curve upwards in close proximity to the domain plant. At the nodes, new rhizomes or roots can be produced. New culms can only form at the very tip of the rhizome. It is this feature that causes them to curve upwards and exhibit the clumping behavior. An advanced pachymorph system is very compact near the base of the plant, making removal or transplant of the bamboo exceptionally difficult.

The leptomorph rhizome system is found in running bamboos. In contrast to the pachymorph system, the rhizomes have a tendency to branch away from the domain plant. The rhizomes are generally long and thin in appearance and some species can send the rhizomes up to 20 feet away in a single growing season. At the nodes, they have the ability to produce buds that will form either new culms or rhizomes. Bamboos with a pachymorph rhizome system will be spaced over a wide area. They are invasive by design and it can be extremely difficult to remove a well established plant.

Roots – The primary function of roots in bamboo is to anchor the culm to the ground. Without a root system, the culm would be at vulnerable to damage from severe weather. This also allows the culm to hold more weight, giving it the ability to grow more leaves over wider distances. The roots do store nutrients, however this is not their primary function. In appearance, the roots are typically symmetrical in size and shape. They form at the base of the culm from the rhizome nodes, and generally go no deeper than one foot below the surface.

Fig-2.3.2: Typical Bamboo Root System Seen in the Phyllostachys Genus.

Culms – Culms are the most visibly distinguishable feature of a bamboo plant. Culms can vary in size, shape, color, and even smell. The appearance can range from thick or thin, tall or short, erect or bent, and can exhibit irregular patterns such as those found in Tortoise Shell Bamboo (P. heterocycla f . heterocycla 'Kiko'). Most culms are round in shape, but some species can take on a square like appearance. The color of the culms also has a wide range of characteristics. Although the majority of bamboos are green, they can also be brown, black, yellow, or striped. One of the most popular garden bamboos, Black Bamboo (Phyllostachys nigra), is unique in the fact that the culms exhibit a nearly jet black color. The culms can also very in smell. One of the most interesting examples is Incense Bamboo (Phyllostachys atrovaginata), which has a waxy coat on the culms that emits a pleasant fragrance similar to incense.

New culms will generally emerge in the springtime, however timing will vary among species. As the culm shoots from the soil it will have already reached its maximum diameter, or girth. The newly emerging culm will grow rapidly and reach its final height by the end of the first growing season. The final size is determined by the local growing conditions, as well as the age and size of the bamboo grove.

Fig-2.3.3: Bamboo Culms with Significant Color Variation.

Branches - The majority of bamboo species will grow multiple branches from a single bud, located at the node. Some genera, such as Chusquea, have the ability to grow multiple buds at from each node.

Leaves – Leaves are present at every main portion of the bamboo plant, which includes the rhizomes, culm, and branches. The anatomy of the leaf itself includes a blade, sheath, and ligule. Leaves are first present in the rhizome where they are almost completely comprised of the sheath. At this stage, leaves serve as a protective cover to encase the rhizome as it travels underground. After the rhizome shoots through the soil and becomes a culm, the blade will become the predominant feature. The blade provides the photosynthetic function of the plant by converting sunlight into energy. The appearance of the blade varies among species. In some species the leaves are very large and less numerous, while other species have a large amount of very small leaves. The appearance of leaves plays a large role in the identification of bamboo.

2.4 The Behavior of Bamboo

In their most basic form, bamboos are evergreen tree-like grasses with woody stems. It is difficult to precisely describe the growth characteristics of bamboo because its behavior is dependent on the local conditions of the growing site. A bamboo growing in ideal conditions can look and behave much different from a bamboo growing inadequate conditions. In this section we describe the behaviors that are most important to consider when growing bamboo.

The most distinguishable characteristic of bamboo is the root system, which is comprised of a group of rhizomes. Rhizomes are stems that migrate from the central plant to establish new territory. As the rhizomes spread underground, they will eventually travel upwards to create a new culm. This process takes place each year and is observed when new shoots becomes visible arising from the soil. Depending on the variety of bamboo and growing conditions, this normally observed in the spring season. The behavior of rhizomes is put into two distinct categories, running and clumping.

Running Bamboos (Monopodial) – Running bamboos are characterized as having self-propagating rhizomes which travel underground, and eventually breech the surface to create a Culm. The rhizomes travel horizontally, and have the ability to move through 20 feet of soil in a single season. The direction and distance of rhizome growth is unpredictable. They are most commonly found naturally in temperate regions, with the most notable genera being Phyllostachys and Pleioblastus.

Fig-2.4.1: Giant Running Bamboos can Spread Great Distances.

Most varieties are cold hardy and are able to survive in below freezing temperatures. Running bamboos are invasive by nature and will spread rapidly if not controlled. This can be a problem when attempting to grow running bamboos in an isolated section of your garden. The most common remedy is to install a rhizome barrier around central plant stop the spread. Check out our article on rhizome barrier installation for more details.

Clumping Bamboos (Sympodial) – Clumping bamboos are characterized as having upward curving rhizomes that grow off of each other. The rhizomes are thicker and shorter than those found in running bamboos, and lack the ability to spread over wide areas. They curve upwards and new culms can only form from the tip of the rhizome, which causes the culms to remain in close proximity to the central plant. This makes clumping bamboos the ideal choice for creating hedges and privacy screens. The most common genus is Bambusa and is primarily found in tropical regions. Clumping bamboos are generally less cold hardy than running bamboos and extra precautions must be taken if the plant will be exposed to frost and freezing temperatures.

Fig-2.4.2: Clumping Bamboo, Bambusa multiplex. (Photo: KENPEI)

Culms – Culms are the most visibly distinguishable feature of a bamboo plant. Culms can vary in size, shape, color, and even smell. The appearance can range from thick or thin, tall or short, erect or bent, and can exhibit irregular patterns such as those found in Tortoise Shell Bamboo (P. heterocycla f . heterocycla 'Kiko'). Most culms are round in shape, but some species can take on a square like appearance. The color of the culms also has a wide range of characteristics. Although the majority of bamboos are green, they can also be brown, black, yellow, or striped. One of the most popular garden bamboos, Black Bamboo (Phyllostachys nigra), is unique in the fact that the culms exhibit a nearly jet black color. The culms can also very in smell. One of the most interesting examples is Incense Bamboo (Phyllostachys atrovaginata), which has a waxy coat on the culms that emits a pleasant fragrance similar to incense.

New culms will generally emerge in the springtime, however timing will vary among species. A new culm is very vulnerable to damage from the environment in the first several weeks after shooting. In fact, it takes nearly 3 growing seasons for most culms to become fully hardened. It is good practice to keep new culms protected from possibly destructive agents, such as wind or animals. It is also easy to accidentally step on top of a shoot within the first couple days of emergence. Extra care needs to be taken when walking near the bamboo during the weeks new shoots start to develop. A newly sprouting bamboo shoot will be covered by overlapping sheaths which are usually brown in color with a layer of fuzz. These sheaths help protect the soft outer tissue of the culm and provide the hormones necessary for rapid growth. Growth of the culm will be inhibited if these sheaths are removed. Eventually they will fall of naturally and can even be collected for use in an organic mulch mixture.

Fig-2.4.3.: Moso Bamboo Culms.

Branches and Leaves – As the culm sheaths fall off, branches will start to grow from the nodes at each section of the culm. The timing and appearance of branches can vary substantially among the different genera. In many running bamboos, such as Phyllostachys, the branches will start to grow almost immediately after the protective sheaths fall off. In other bamboos, branches may not appear for an entire year. More than anything, the behavior of the branches serves as a method of identifying the species of bamboo. The behavior of branches and leaves rarely poses any problems for a cultivator.

Fig-2.4.4: Bamboo Leaves and Branches. (Photo: Erin Silversmith)

2.5 Properties of bamboo

Anatomically, bamboo is quite different from wood coming from gynosperms and dicotyledonous angiosperms (Ghosh and Negi, 1959). All the growth in bamboo occurs longitudinally and there is no lateral or radial growth as in trees. Characteristically, bamboo has a hollow stem, or culm (solid in some species only), which is closed at frequent intervals called nodes. The bamboo culm comprises about 50% parenchyma, 40% fibres and 10% vessels and sieve tubes (Liese 1987). Fibre percentage is higher

in the outer one- third of the wall and in the upper part of the culm, contributing to its superior slenderness (Grosser and Liese, 1971). Most fibres have a thick polylamellate secondary wall (Parameswaran and Liese, 1976). The typical tertiary wall present in most woody cells of gymnosperms and angiosperms is not present. Similarly, bamboos do not develop reaction wood, which is most common in tree species due to agting. Fibres in bamboos are grouped in bundles and sheaths around the vessels. The epiderma1 walls consist of an outer and inner layer; the latter is highly lignified. The outer layer contains cellulose and pectin with a wax coating. Silica particles also exist in the peripheral parts of the culm. These anatomical features are responsible for the poor penetration of preservatives into round culms during treatment. Although vessel elements in bamboo are easily permeable, lateral flow is restrictedbecause of the absence of ray cells.

Bamboo consists of 50-70s hemicellulose, 30% pentosans, and 20-25% lignin (Tamolang et al, 1980; Chenef al, 1985). Ninety percent of the hemicellulose is xylan with a structure intermediate between hardwood and softwood xylans (Higuchi, 1980). The lignin present in

bamboos is unique, and undergoes changes during the elongation of the culm (Itoh and Shimaji, 1981). Bamboo is known to be rich in silica (0.5 to 4 %) , but the entire silica is located in the epidermis layers, with hardly any silica in the rest of the wall. Bamboos also have minor amounts of resins, waxes and tannins. None of these, however, have enough toxicity to impart any natural durability. On the other hand, the presence of large amounts of starch makes bamboo highly susceptible to attack by staining fungi and powder-post beetles (Beeson, 1941; Gardener, 1945; Mathew and Nair, 1988; Gnanaharan *et* al, 1993). Laboratory tests have indicated that bamboo is more prone to both soft rot and white rot attack than to brown rot (Liese, 1959). The natural durability of bamboo is very low and depends on species, climatic conditions and type of use. Early observations on durability of bamboo were based on the performance of full sized structures.

1)Because bamboo grains are aligned parallel in the axial (vertical) direction, bamboo is an anisometric material. This means the the mechanical properties depend on the direction of the force; for instance, compression of the bamboo in the axial direction will result in a different compressive strength then compression in the radial direction.
2) Generally speaking, dry bamboo has higher mechanical properties than wet bamboo. Raw bamboo naturally has a high moisture content, where MC = 100*(wet weight-dry weight)/dry weight. This moisture content can be brought down by using various treatment methods (see "Bamboo Treatments").
3) Generally, smaller bamboo has stronger mechanical properties (such as ultimate compressive strength) for its size. However, larger bamboo can withstand larger forces.
4) Thicker walls have better mechanical properties generally.
5) As the distance to the node decreases, the mechanical properties improve.
6) The height along the bamboo (when measured from the ground) affects its properties. Generally, the part of the bamboo nearer the bottom has stronger properties.
7) Very young bamboo and old bamboo have weaker mechanical properties than bamboo that is around the age of 3-7 years.
8) The species of bamboo also matters, some are not useful as a building material.

Because so many properties affect bamboo, it can be difficult to find bamboo property values which are reliable across a large number of cases.

2.6 Bamboo Treatability:

The tissue of bamboos is built up ot parenchyma tous cells and vascular bundles (vessels and thick-walled fibres). The vascular bundles uniformly distributed inside the culm (Fig 2.6.1).

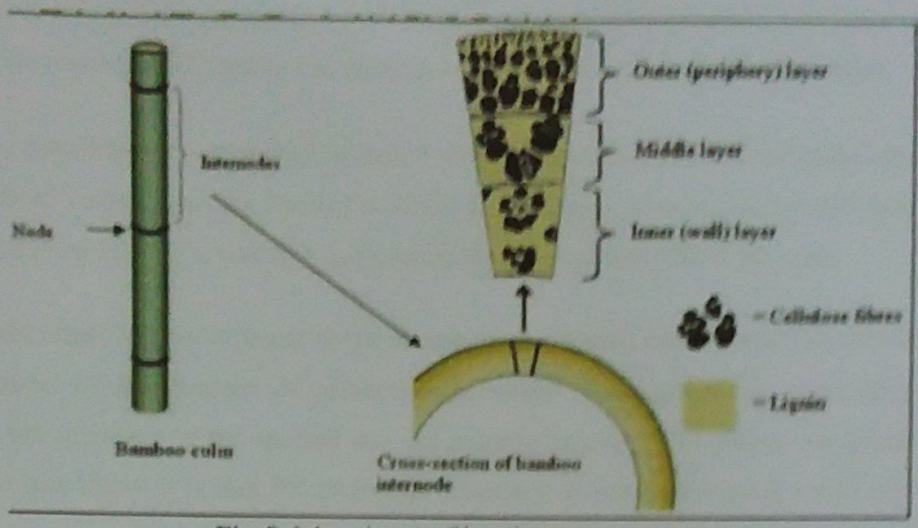

Fig-2.6.1 : tissue of bamboos

Numerous smaller ones are present towards the outer portion, while larger but fewer bundles are found towards the central part of the culm (Kumar and Dobriyal, 1992). Bamboo has no radial cell elements like the rays in wood. The outer wall is covered by a thin and hard layer and is less permeable than the inner layer. Nutrients are stored in the ground tissue of parenchyma cells, which constitute up to 50% of the tissue (Liese, 1987). Bamboos behave entirely differently from wood during treatment with preservative. The vascular bundles play an important role in preservative treatment. The axial flow is quite rapid in green bamboos, because of the end-to-end alignment of vessels. The degree of penetration decreases as the distance from the conducting vessel increases. The larger vessels tend to get a larger amount of preservative than the smaller vessels. (Both larger and smaller vessels belong to metaxylem whereas the protoxylem consists of tracheid-like elements.) Since vessels occupy a mere 10% of the culm volume, the penetration of preservatives to other tissues surrounding the vessels assumes more importance because untreated pockets, especially in parenchyma tissues, can lead to early destruction by fungi (Liese, 1959).

2.7 Penetration and Retention of Preservative

Retention, usually expressed as kilograms of preservative per cubic metre of bamboo or wood (pounds per cubic foot), is the amount of preservative retained in the bamboo or wood after completion of the treating cycle and is one measure of the degree of protection provided.

Plywood can be penetrated by preservatives more readily than solid wood of the same species because the veneer cutting process opens the wood grain. These minute fissures are hard to detect witht the naked eye but are readily penetrated by preservatives under pressure.

Penetration is the depth to which preservative chemicals are forced into the bamboo or wood. It is an indication of the amount of protection provided. The amount of penetration is determined by the qualities of the species and the treating process. The greater the depth of penetration, the less likely it is that the protected boundary of pressure-treated wood will be breached.

2.8 Bamboo treatment:

Many developing counties (where most bamboos grow) suffer a lack of awareness and professional treatment facilities. Furthermore, not all curing methods ensure satisfying results which leads to uncertainties about the advantages of using bamboo all together.

A lot of bamboos used for structural purposes in rural housing are untreated (or the wrong species) and deteriorate in just a couple of years, hence the reason bamboo is still considered as a poor man's timber.

Not only does the incorrect use affect the reputation of bamboo, it also puts heavy pressure on the resource, since frequent replacement is necessary.

Chemical preservatives should be used to protect bamboo products from such degradation. These are well established methods providing good protection even in adverse conditions.

The selection of the appropriate treatment method depends on various factors:

- State of the bamboo; green or dry.
- Form of the bamboo: round bamboo or splits.

- End applications; in ground contact, exposed to atmosphere, undercover, structural/non-structural.
- Scale; quantity to be treated and available time.
- Potential causes of decay; biotic (fungus/insects) and abiotic (cracks/weathering).

We think it is important to promote the correct use of bamboo in order to increase the durability, utilization, and popularity of this versatile and environmentally friendly material. Increasing the shelve-life of bamboo to 50 years or more is certainly possible by applying the appropriate treatments which is also more economical and sustainable in the long run.

Chemical Bamboo Preservation

Chemical preservation (with or without the help of special equipment) ensures long term protection. Depending upon the method of bamboo treatment, chemical preservatives can impart short term or long term protection.

With a few exceptions, chemical preservatives to protect bamboo against biological attacks and degradation are toxic. Selection and application has to be done with great care to meet performance, environment requirements and safety.

Depending upon the carrier solvents, bamboo preservatives are divided into 2 different categories: Non-fixing and fixing type preservatives. Non-fixing preservatives will leach out the bamboo when exposed to rain. In other words non-fixing type preservatives are NOT suited for outdoor use.

Non-Fixing Type Preservatives

Non-fixing bamboo preservatives mainly consist of boron salts, which are effective against borers, termites and fungi (except soft rot fungi). These boron salts are dissolved in water. After treatment, the water evaporates leaving the salts inside the bamboo. They are not toxic and can be used for treating bamboo products like baskets, dry containers, etc. which come in contact with food products.

Boric Acid Borax

Curing bamboo with borax and boric acid is the most popular bamboo preservation method (for indoor use) around the world because it is effective and more environmentally friendly than other wood preservatives.

The combination of boric acid and borax in a ratio of 1:1.5 is an alkaline salt called: Disodium octaborate tetrahydrate ($Na_2B_8O_{13} \times 4H_2O$) and is available in pre-mixed powder form, usually under the commercial names: Tim-Bor or Solu Bor, among others.

Disodium octaborate tetrahydrate is a white, odorless, powdered substance that is not flammable, cumbustible, or explosive and has acute low oral and dermal toxicity. The product itself is fire retardent and shows no hazardous decomposition.

This salt, is used as an insecticide and fungicide, and is also effective against fungi and algae. It has an infinite shelf life and is not affected by temperature. Diluted with water, bamboo can be impregnated, submerged or sprayed with this chemical.

Formula (1):

- boric acid / borax
- ratio 1:1.5

Formula (2):

- boric acid / borax / sodium dichromate
- ratio 2:2:0.5

Recommended concentration:

- 4-5% indoor use (not exposed to weather or ground contact)

How to Interpret the Terms: 'Ratio' and 'Concentration'?

The ratio of the chemical solution is based on kilograms per 100 liters of water.

For example, if you see this:

- boric acid / borax / sodium dichromate
- ratio 2:2:0.5

It actually means this:

- a mixture of 2 kg of boric acid / 2 kg of borax / 500 gr of sodium dichromate in 100 liters of water.

The above example is the equivalent of 4,5% concentration. If you want to ramp this up to a concentration of 9% you just have to double the mixture like this:

- a mixture of 4 kg of boric acid / 4 kg of borax / 1 kg of sodium dichromate in 100 liters of water.

Fixing Type Preservatives

These chemical bamboo preservation formulations are proportionate mixtures of different salts which interact with each other in the presence of bamboo and become chemically fixed. In principle, the degree of fixation and efficacy depends upon the nature of the components and their combination and concentration.

For example, Chromium is responsible for fixation, copper is effective against decay fungi and soft rot and the third compound acts against insect and fungus. The process of fixation requires some weeks during which the material should be stored under cover. Slow fixation is preferred in case of bamboo as it allows diffusion and better distribution of preserving salts.

Chromated Copper Arsenate (CCA)

CCA is a heavy duty broad spectrum chemical bamboo preservative patented as AsCu. It has been found to provide protection for 50 years or more. Outdoor use is recommended only due to the arsenic component, which can also causes a green coloration on the bamboo.

Formula:

- arsenic pentoxide / copper sulphate / sodium dichromate
- ratio 1:3:4

Recommended concentration:

- 6% outdoor use (structures exposed to weather but not in contact with ground)
- 10% outdoor use (structures exposed to weather and in ground contact)

Vacuum Pressure Methods

- Conventional vacuum-pressure methods use *pumps* to create vacuum and pressure, thereby producing high pressure gradients and operator control over the process. By contrast the thermal process is limited to atmospheric pressure alone. However, by means of pumps, 10-12 atmospheres of pressure can easily and safely be produced. This is equivalent to about 140 to 175 pounds per square inch (psi) in a treating retort or cylinder. Figure indicates the penetration of preservative that might result from vacuum-pressure treatments. Although there are various vacuum-pressure methods available such as the Double Vacuum Process and the Mississippi State University Process, the principal methods used by the U.S. pressure-treating industry are:

- Full cell process (Bethell process)

- Empty cell processes (Lowry and Rueping)
- Modified full cell process

Full cell process

This is the simplest and most common of the vacuum-pressure processes. It was developed by John Bethell in 1838. The full cell (or Bethell) process is used for most of the pressure treatments using chromated copper arsenate (CCA) and pentachlorophenol-based (PCP) preservatives, and a good proportion of the treatments with creosotes.

Features of the full cell process include:

- It gives the deepest possible penetration and the highest loadings (retentions) of preservative with easily-treated species. Virtually all of the air in the wood cells can be replaced with preservative. Sometimes this may produce a higher loading than necessary •

The degree to which penetration and retention of preservative occurs depends on the permeability of the wood. For effective treatment, some species may need special preparation such as incising, steaming, or Boultonizing, which are described in a later section of this lesson.

No vacuum-pressure process is more effective than the full cell in maximizing the uptake or penetration of preservative. The sequence of procedures used in the full cell is summarized below:

- Enclose dried wood (timbers, lumber, poles, etc.) in a pressurable cylinder or retort.
- Use a vacuum pump to remove most of the air from the cylinder. Hold a partial vacuum to allow air to be removed from the wood cells.
- Without releasing the vacuum, allow the cylinder to fill with liquid preservative.
- Apply pressure to the preservative to force it into the wood cell spaces previously occupied by air, now occupied by a partial vacuum.
- When the desired and measured amount of liquid preservative has been absorbed, release the applied pressure and drain the cylinder (initial drain).
- Apply a "final" vacuum to expand the air remaining in the wood. This forces excess liquid to exude from the surfaces and run off.
- Release final vacuum. As the remaining air in the cells contracts, much of the surface wetness will be reabsorbed into the wood (this reduces dripping later).
- Remove the treated wood products from the cylinder

Chapter:3

3. MATERIALS AND METHOD:

3.1 Sample Collection:

Samples of Bamboo of three species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) of three years older was collected from Khulna university Nursery under Forestry and wood technology Discpline.

3.2 Sample Preparation:

Two samples of 6 inches (152.4mm) ,one sample with node and another one internode,was taken from base, middle and top of each full bamboo of particular species.

Fig-3.2.1: Photo of treated bamboo sample of three species

Fig-3.2.1: Photo of bamboo ring sample of three species

Thus twelve green samples of each bamboo species was prepared and Six of which samples of each bamboo species are sent for drying to oven dry in Khulna university forestry and wood technology lab. Six green sample of each bamboo species was sent for CCA-C (As_2CrCuO_9) treatment at wood treatment plant of Nordic wood Limited,Khulna and other oven dried six samples of each full bamboo of particular three species was also sent for CCA-C treatment at wood treatment plant of Nordic wood Limited,Khulna.4% CCA solution was used to treat bamboo sample with a target of 100% penetration and 20 kg/m³ retention. Twenty four bamboo ring samples of 25mm length of each bamboo species was taken from base, middle and top of each full bamboo of particular species to determine MC and shrinkage percentage of respective three species after oven drying. Thus 36 samples of 6 inches was treated to determine penetration(%) and retention (kg/m³) and 72 bamboo ring samples of 25mm length of three bamboo species sample was measured to determine MC and shrinkage percentage of respective three species.

3.3 Shrinkage and Moisture Content determination:

Density of Sonali, Giant and Kali bamboo were calculated as 0 .71, 0.65 and 0.56 kg/m³ respectively at 18% MC (moisture meter).

Raw bamboo naturally has a high moisture content, where

MC (%) = 100*(wet weight-dry weight)/dry weight

Shrinkage (%) along Diameter = 100*(Green Diameter - Oven Dry Diameter)/ Green Diameter

Shrinkage (%) along Thickness=100*(Green Thickness – Oven Dry Thickness)/Green Thickness

3.4 Bamboo sample treatment:

Pressure treatment is universally used for treating wood and has been adopted for treating bamboo as well. Pressure processes may be employed with any type of preservative. Full cell or Bethel process is used when maximum absorption of the preservative is desired (ground contact use). The bamboo is introduced into the pressure cylinder. The door is tightly closed

and a vacuum of at least 30 cm of mercury is created and maintained for half an hour. The purpose of this operation is to remove as much air as possible from the cells. At the end of the vacuum period, the preservative (4% CCA-C) is introduced into the cylinder. When the cylinder has been filled with preservative, the vacuum pump is stopped and the cylinder is subjected to pressure of 3.5 to 7.0 kg/cm^2. The pressure is held until the desired absorption is obtained, after which the preservative is withdrawn from the cylinder. Finally a vacuum of 33 cm of mercury is applied for about 15 minutes to free the material from the dripping preservative. Specified retention of toxic chemicals during treatment may be obtained by a proper selection of the concentration of the toxic material in the treatment solution and a suitable absorption of the preservative solution, which is controlled by the duration of pressure and vacuum periods

3.5 Penetration determination:

Five boring along thickness was taken from each bamboo sample and these boring sample was soaked with cromazole indicator.

Fig-3.5.1: Photo of boring collection

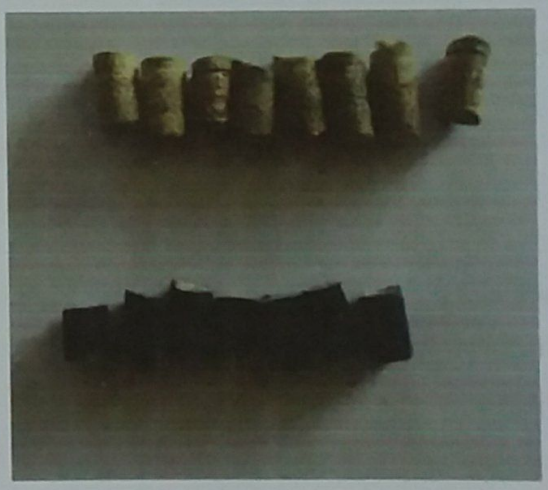

Fig-3.5.2: Photo of Boring sample and color changed boring

Due to preservative reaction with indicator each boring change its color from greenish to blueish purple.After the sun drying each boring cut down of blueish purple and length of color part of each boring sample measured with slide caliper in millimeter (mm).

Fig-3.5.3: Photo of Measuring length of colour portion of Boring sample

Then using following formula penetration(%) was calculated:

Penetration (%) = (length of colored part/ thickness of respective bamboo sample)*100%

3.6 Retention Determination:

Five boring along thickness was taken from each bamboo sample and these boring sample was sent to BREB(Bangladerh Rural Electrification Board) laboratory for acid digestion method of retention determination.

Acid Digestion Method: AWPA (American Wood Preservation Association) standard

Boring Sample Preparation

Determine the density of the bamboo sample in kg per cubic meter. A representative sample is taken and ground to saw dust in a Wiley mill. In this study three boring of each sample is used for determination of retention and in this case the entire sample is used and the volume is determined for calculation rather than using a weight basis.

Reagent:

Concentrated Nitric Acid (70%,15.8 Molar) and Hydrogen Peroxide(50%).

Analytical Procedure:

Accurate measureor weigh of bamboo boring sample into a 250ml Erlenmeyer flask with about three glass beads. For each gram of of bamboo boring sample add15ml of Nitric Acid. Prepare a digestion blank along with the samples.Warm slowly on a hot plate.Increase heat after initial reaction of bron fumes subside and then heat until the solution clears.

Reduce heat, add dropwise 5ml of Hydrogen Peroxide.If the solution is not clear after this treatment increase heat and add dropwise another 5ml Hydrogen Peroxide.

Quantitively transfer the digest to a 200ml volumetric flask dependent on the sample weight.

Determination of chromium:

i) Place 20 ml sample solution in a 500ml Erlenmeyer flask and add sufficient amount (180ml) of water to make a total volume of about 200ml.

ii)Add 3ml of phosphoric acid and 6 ml of 1:1 sulfuric acid and stir the solution well

iii) Immediately pipet exactly 10ml of ferrous ammonium sulfate solution into the solution and add 10 drops of barium diphenylamine sulfonate solution

iv) Immediately titrate the solution with standard 0.2000 normal potassium dichromate solution from a 10 ml class A buret.

v) The end point has been reached when the color of the solution becomes deeply purple or deep greenish.

Calculation:

Amount of preservative (CrO_3) kg/m³ **= (Titration Difference(ml)*Normality*A liquid factor(3.334)*Density of bamboo ample)/100*20% of boring weight** (AWPA standard)

Determination of copper:

i) Place 20 ml sample solution in a 300ml wide-mouth Erlenmeyer flask and add 10ml of water .Add 10 ml concentrated hydrochloride acid and a few glass beads. Add 15ml alcohol carefully, warm to boiling and heat until all chromium is reduced, as evidenced by the absence of any yellowish-green color. The solution should be clear bluish-green.(with ammonical copper zinc arsenate a hood should be used for the boiling)

ii)Wah down side of flask with water.Boil for 1 minute,cool and neutralized cautiously ith concentrated ammonium hydroxide until a permanent precipitate jut forms.With sample containing small amounts of copper, a precipitate may not form. In this case,adjust the pH to slightly basic with concentrated ammonium hydroxide as measured with pH indicating paper.Add concentrated sulfuric acid drop by drop until the precipitate just dissolves or until the solution becomes acidic.Boil down to a volume of 30ml.Cool to below 20°C.Dilute to 125ml.

iii) Add 10ml 20% potassium iodide solution and 5ml 20% sodium thiocyanate solution and mix thoroughly by rotating the flask.Titrate from a10ml class A buret with 0.05N sodium thiosulfate solution, adding 2ml starch solution just before the brownish color of the iodine disappears.Stop the titration when the color changes from dark blue to light green.With ammonical copper zinc arsenate, the end point change is from dark blue to cream color.

iv)For standardization of the 0.1N sodium thiosulfate solution dissolve in a 250ml Erlenmeyer flask an accurately weighed portion of pure copper foil or shot(about 0.25g) in 10ml of concentrated nitric acid. Evaporate the solution until about 3-4ml remains.Cool wash down sides of flask with distilled water. Add 10 ml 5% urea solution and boil 3 minutes.Cool the solution to room temperature and add concentrated ammonium hydroxide cautiously until the solution just turns to a deep blue color. The use of a dropping bottle facilitate this step. Add 5ml glacial acetic acid,swirl and wash down the sides of the flask with distilled water. Dilute to 50ml with distilled water and Cool to room temperature.Add 10ml 20% potassium iodide solution ,do not swirl,and 5ml of 20% sodium thiocyanate solution.Tirate with sodium thiosulfate have been added, swirlthe flask and c ontinue the titration until the solution color changes from dark brown to light tan. Add 5ml of fresh starch indicator solution and continue the titration until the solution color just changes from blue to cream white.

Calculation:

Amount of preservative(CuO) = (Sample Titration (ml)*Normality* A liquid factor(7.96) Density of bamboo ample)/100*40% of boring weight kg/m³

Determination of Arsenic:

i) Place 20 ml sample solution in a 250ml wide-mouth Erlenmeyer flask and add sufficient amount (30ml) of water to make a total volume of about 50ml.

ii)Add 50ml of hydrochloride acid

iii) Add 20 ml of hypophosphorous acid,mix thoroughly and arm the solution on a steam bath until a precipitate form.

iv) Boil the mixture gently for about 15 minutes

v)With the aid of suction, filter the hot solution through a 10ml Gooch crucible-containing a Whatman 934 AH glass microfiber filter of equivalent, washing the flask and precipitate thoroughly with water.

vi) place the crucible-containing the precipitate in the same flask in which precipitation was carried out.Discard the filtrate.

vii)Pour 10ml of sulfuric acid into the flask and heat over an open flame,while agitating,until copious fumes are evolved.

viii)Allow the flask and contents to cool and then add 100ml of water very slowly and carefully,especially at first,as much heat is generated during this addition.

ix) next add 5ml of hydrochloride acid and 2 drops of methyl orange solution and immediately titrate with standard potassium bromated solution from a 10ml class A buret.

x)When the solution becomes colorless the end point has been reached.

Calculation:

Amount of preservative (AsO_5) = (Titration Difference(ml)*Normality* A liquid factor (5.746)*Density of bamboo ample)/100*40% of boring weight kg/m^3

Hence,

Total preservative Retention (kg/m^3) **= Amount of preservative (CrO_3) + Amount of preservative(CuO)+ Amount of preservative(AsO_5)**

Chapter:4

4. RESULTS AND DISCUSSION:

4.1 Compring vertical distribution of moisture content percentage in three bamboo species:

Bamboo possesses high moisture content. In this study Green bamboo of three species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) have 80.4%, 73.5% and 75.30% percent moisture content (oven-dry weight basis) respectively. In Giant (Dendrocalamus giganteus) bamboo the vertical distribution of moisture content is 76.15% to the top and 84.29% to the base. Vertical moisture distribution of Sonali(Bambusa gigansula) are 69.35% percent to top ,73.46% to middle and 77.69% to the base. On the other hand in Kali (Gigantochola andamanica) bamboo the vertical moisture distribution are 69.12% to the top, 74.69% to the middle and 82.09 % percent to the base. Hence The moisture content varies along the height for green bamboo or at any time after harvesting. The top portions had consistently lower moisture content than the middle or basal at all stages of seasoning.

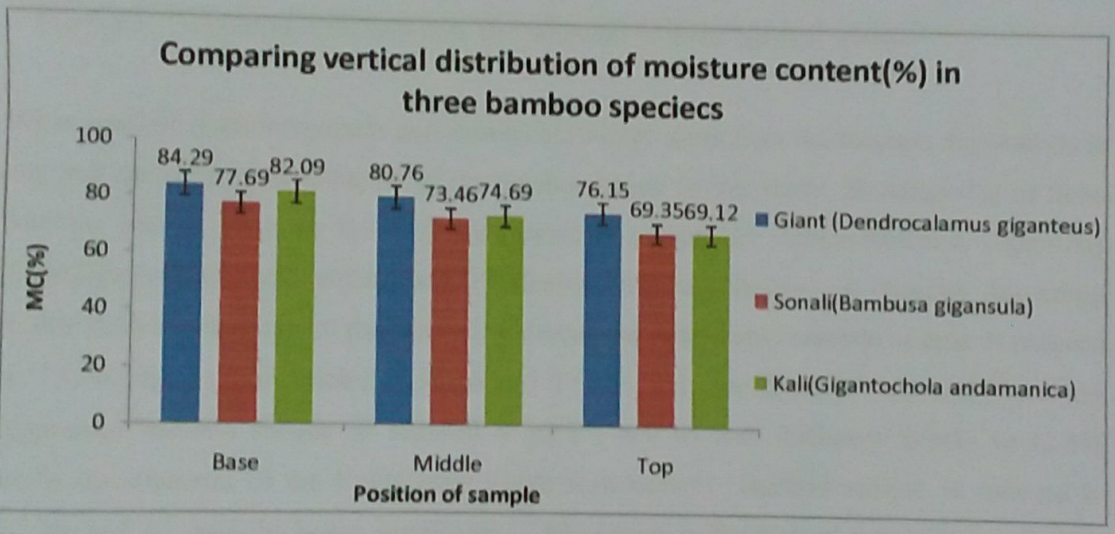

Fig-4.1.1: Compring moisture content (%) distribution to the base, middle and top of three bamboo species

4.2 Comparing shrinkage percentage of three bamboo species:

Drying bamboo poles requires more time than wood of similar density. This because bamboo possess hygroscopic materials (compound that easily absorbs moisture) that may contain 50-60% moisture content, depending on the felling season, area of growth and species.

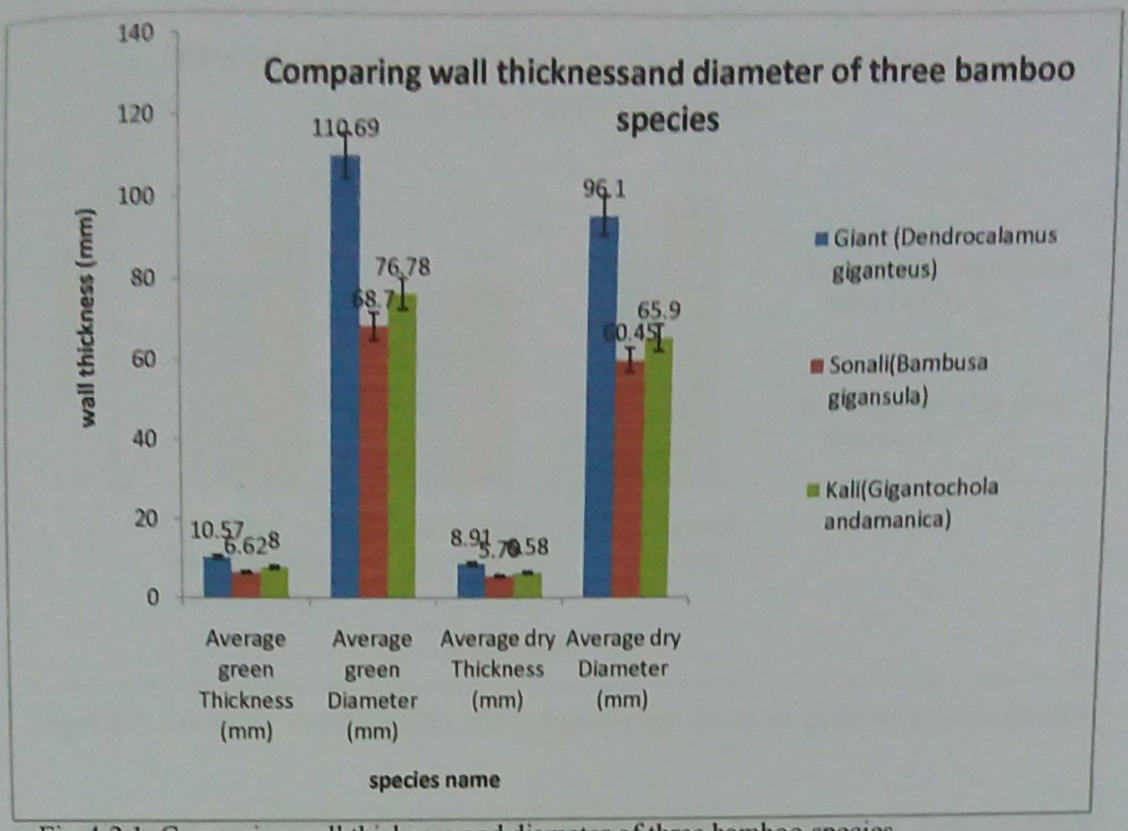

Fig-4.2.1: Comparing wall thickness and diameter of three bamboo species

When bamboo dries it contracts and shrinks.Shrinkage starts from the moment the bamboo is cut, and can reduce the diameter of the bamboo poles. In this study, Shrinkage(%) of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) along diameter and along thickness is checked. According to this study the diameter of the Giant (Dendrocalamus giganteus) bamboo sample is reduced to 13.2% and its wall thickness shrinks to 15.7%. and the diameter of Sonali(Bambusa gigansula) bamboo sample is reduced to 12.1% and its wall thickness shrinks to 12.8% while the diameter of the Kali(Gigantochola andamanica) bamboo sample is reduced to 10.5% and its wall thickness shrinks to 17.8% which is the highest among three species. Hence green bamboo poles should not be used in construction. Since green bamboos are subject to shrinkage, joints and terminals may loosen after just a few weeks. Green bamboo is also more attractive to insects and microorganisms, than dry bamboo.

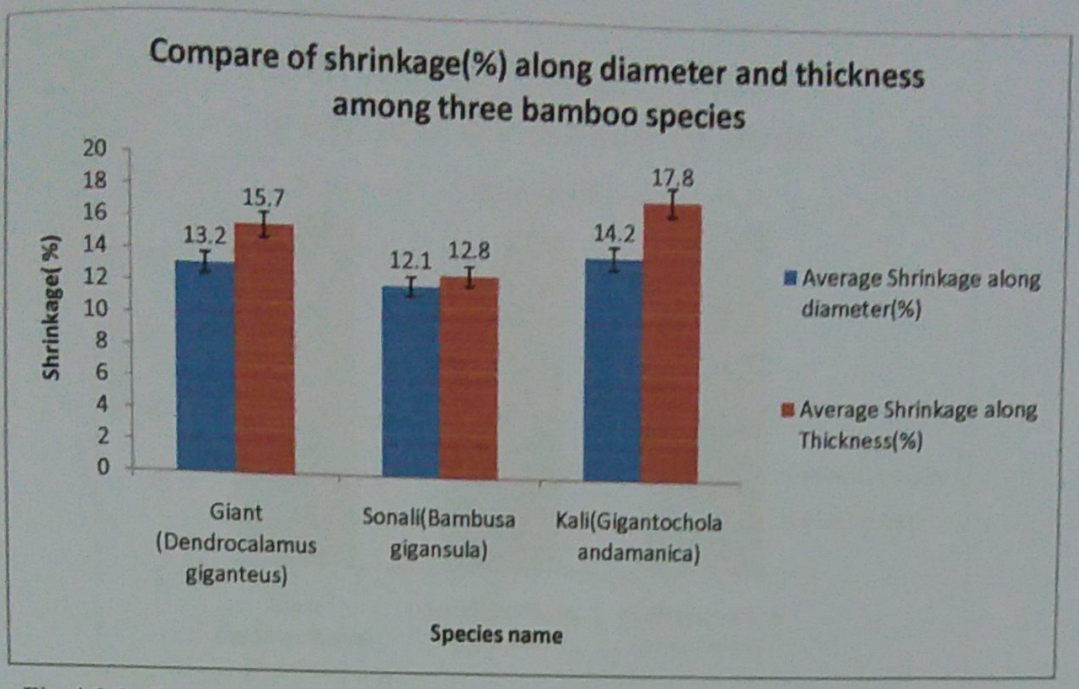

Fig-4.2.2: Compring shrinkage (%) along diameter and thickness of three bamboo species

4.3 Comparing Penetration and Retention of green and dry sample of three bamboo species:

Chromated copper arsenate (CCA) treatability tests on full cell pressure impregnated (with 4% CCA solution) and oven dried bamboo pole of 6 inches of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) from Khulna university campus revealed initial insignificant leaching of CCA within first week and no leaching in next week. Use of low concentration of CCA, release of particle form of CCA due to exposure of bamboo blocks by cutting and presence of water soluble extractives in bamboo might be the causes for initial leaching of CCA. Retention of preservative is related to durability of bamboo. According to this study green samples show lower penetration percentage and retention than dried samples. In Giant (Dendrocalamus giganteus) green bamboo samples exhibit 36.26% penetration of wall thickness from inner ide as Bamboo is also known to be rich in silica (0.5 to 4%), but the entire silica is located in the outer layer (1 mm), with hardly any silica in the rest of the wall. and 6.39 kg/m^3 retention while dry bamboo samples show much more penetration and retention like 92.94% and 16.48 kg/m^3 respectively. In Sonali (Bambusa gigansula) green bamboo samples exhibit 36.05% penetration and 5.38 kg/m^3 retention while dry samples show 91.04% penetration and 15.42 kg/m^3 retention. On the other hand Kali (Gigantochola andamanica) green bamboo samples exhibit 44.17% penetration and 7.48 kg/m^3 retention while dry samples show 94.27%

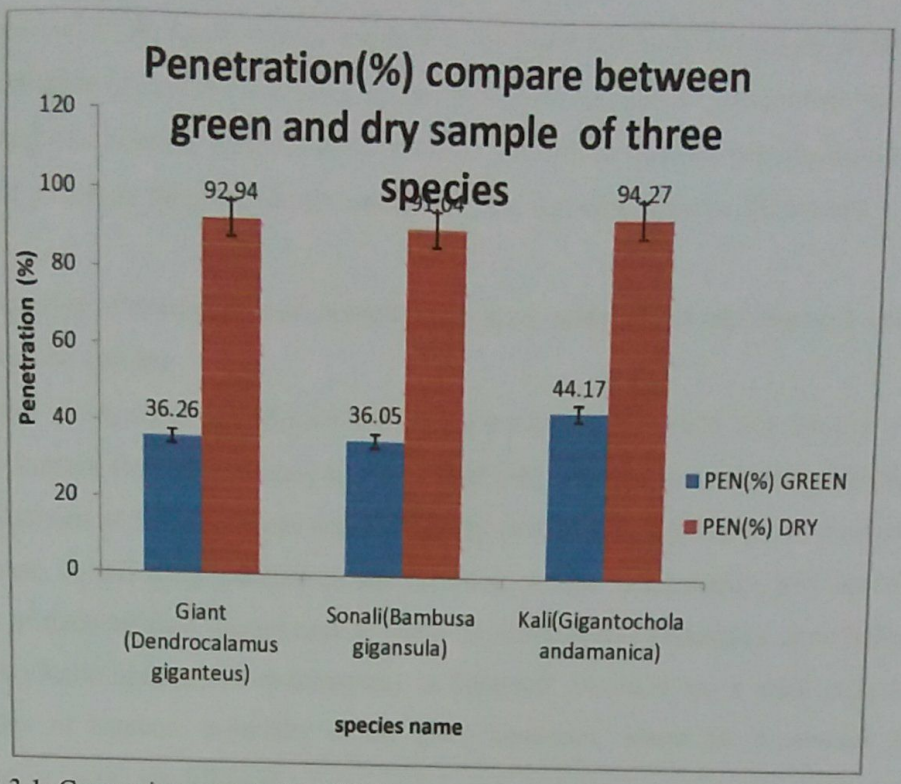

Fig-4.3.1: Comparing penetration (%) between green and dry samples of three bamboo species

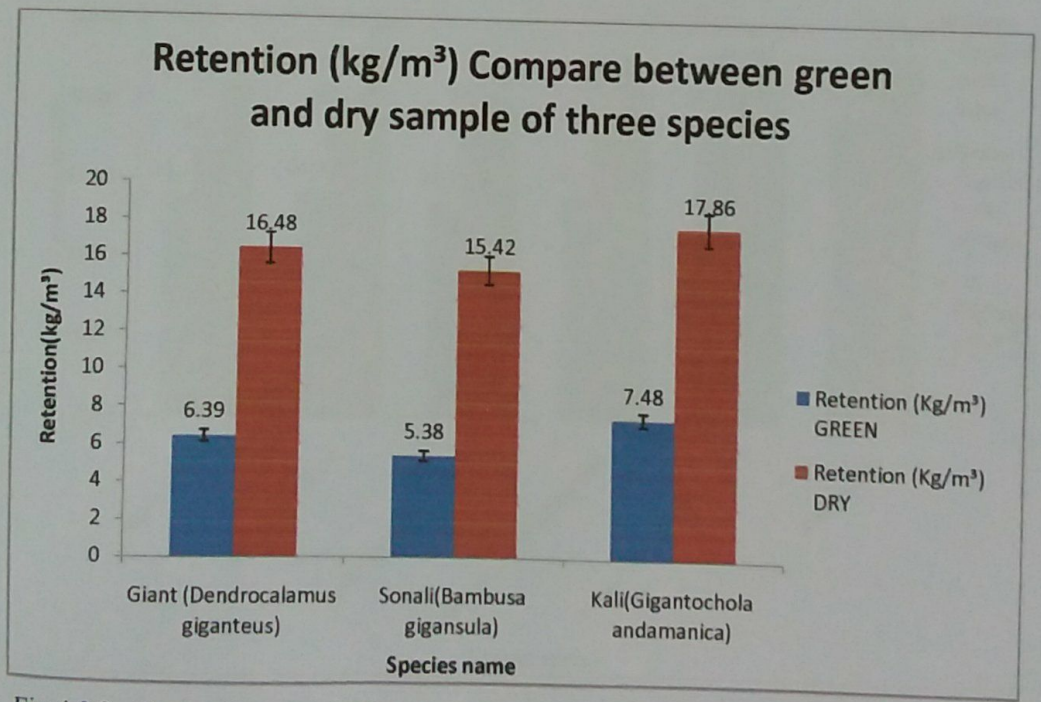

Fig-4.3.2 : Comparing retention between green and dry samples of three bamboo species

penetration and 17.86 kg/m³ retention which is the highest penetration among three species. The preservation of bamboo structures against biological hazards is an important requirement for utilizing this valuable lignocellulose resource. Compared with the preservation of timber in tropical countries, there are certain similarities, but also considerable differences.

4.4 Comparing Penetration and retention at base, middle and top of green sample of three bamboo species:

Treatability is regulated by position (the upper portion of the culm has always a lower moisture content than the bottom), age (6-Y years old bamboos contain less moisture than young bamboos of 3-4 years), and season of telling (maximum moisture is present during the rainyseason. In this study penetration and retention to the base, middle and top of green samples of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) is observed. Moisture has a great influence on treatability of bamboo, especially in the green condition, where the movement of the preservative occurs via diffusion.

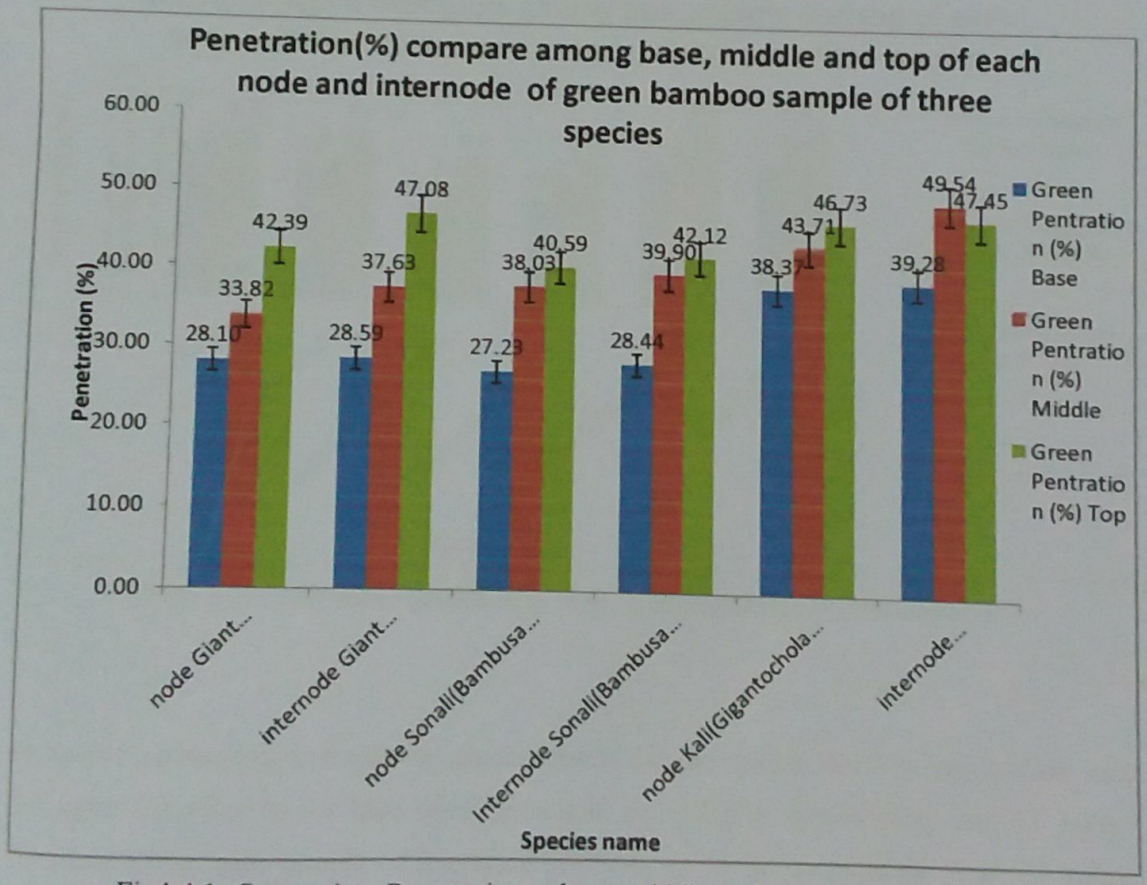

Fig4.4.1: Comparing Penetration at base, middle and top of green bamboo

In Giant (Dendrocalamus giganteus) green bamboo sample exhibit 28.10 % penetration and 5.5 kg/m³ retention to the base of node sample and 28.59% penetration and 5.8 kg/m³ retention to the base of inter node samples; 33.82 % penetration and 6.1 kg/m³ retention to the middle node sample and 37.63% penetration and 6.3 kg/m³ retention to the middle internode sample and 42.39 % penetration and 7.3 kg/m³ retention to the top node sample and 47.08 % penetration and 7.3 kg/m³ retention to the top inter node samples of inner side of bamboo.

In Sonali (Bambusa gigansula) green bamboo sample exhibit 27.23 % penetration and 4.4 kg/m³ retention to the base of node sample and 28.44% penetration and 4.6 kg/m³ retention to the base sample of internode position; 40.59 % penetration and 5.1 kg/m³ retention to the middle node sample and 39.90% penetration and 5.6 kg/m³ retention to the middle internode sample and 40.59 % penetration and 6.2 kg/m³ retention to the top node sample and 42.12 % penetration and 6.3 kg/m³ retention to the top inter node samples.

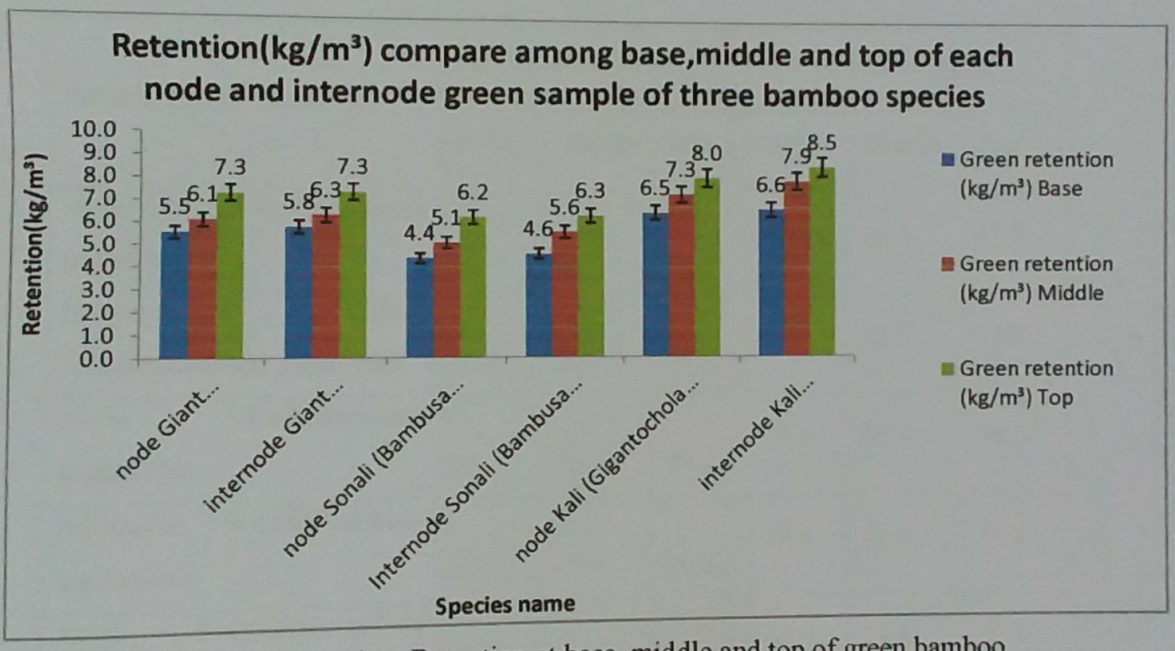

Fig4.4.2: Comparing Retention at base, middle and top of green bamboo

In Kali (Gigantochola andamanica) green bamboo sample exhibit 38.37 % penetration and 6.5 kg/m³ retention to the base of node sample and 39.23% penetration and 6.6 kg/m³ retention to the base sample of internode position; 43.71 % penetration and 7.3 kg/m³ retention to the middle node sample and 49.54 % penetration and 7.9 kg/m³ retention to the

middle internode sample and 46.73 % penetration and 8 kg/m³ retention to the top node sample and 47.45 % penetration and 8.5 kg/m³ retention to the top inter node samples. According to this study penetration percentage and retention differ from base to top of same bamboo.Thus penetration percentage and retention to the top is higher than bottom portion of same bamboo due to lower moisture content percentage to the top.

4.5 Comparing penetration and retention at base, middle and top of dry sample of three bamboo species:

Treatability is controlled by moisture content present in bamboo. Dry bamboo show better penetration and retention than green bamboo. In this study penetration and retention to the base, middle and top of dry samples with node and internode position of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula) Kali(Gigantochola andamanica) is determined.

Sl	Sample name	Dry Penetration (%)			Dry retention (kg/m³)		
		Base	Middle	Top	Base	Middle	Top
1	Node Giant (Dendrocalamus giganteus)	82.5	95.6	98.6	15.6	16.5	17.3
2	Internode Giant (Dendrocalamus giganteus)	84.8	97.9	98.3	15.6	16.7	17.3
3	Node Sonali(Bambusa gigansula)	85.0	85.3	99.1	14.2	15.3	16.1
4	Internode Sonali(Bambusa gigansula)	85.3	92.4	99.2	14.4	15.4	17.1
5	Node Kali(Gigantochola andamanica)	96.4	85.5	97.1	16.9	17.9	18.3
6	Internode Kali(Gigantochola andamanica)	97.7	89.3	99.6	17.4	18.1	18.6
Average		88.61	91.00	98.65	15.7	16.6	17.4

Table-4.5.1: Comparing Penetration and Retention at base, middle and top of dry bamboo

In Giant (Dendrocalamus giganteus) dry bamboo node sample exhibit 82.5 % penetration with15.6 kg/m^3 retention to the base and 98.6 % penetration with 17.3kg/m^3 retention to the top while dry bamboo internode sample of this species show 84.8 % penetration with15.6 kg/m^3 retention to the base and 98.3 % penetration with 17.3 kg/m^3 retention to the top.

In Sonali(Bambusa gigansula) dry bamboo node sample exhibit 85 % penetration with14.2 kg/m^3 retention to the base and 99.1 % penetration with 16.1 kg/m^3 retention to the top while dry bamboo internode sample of this species show 85.3 % penetration with14.4 kg/m^3 retention to the base and 99.2 % penetration with 17.1 kg/m^3 retention to the top.

In Kali(Gigantochola andamanica) dry bamboo node sample exhibit 96.4 % penetration with16.9 kg/m^3 retention to the base and 97.1 % penetration with 18.3 kg/m^3 retention to the top while dry bamboo internode sample of this species show 97.7 % penetration with17.4 kg/m^3 retention to the base and 99.6 % penetration with 18.6 kg/m^3 retention to the top.

Chapter:5

5. CONCLUSION AND RECOMMENDATIONS:

5.1 Conclusion

Bamboo is a giant grass and not a tree. Bamboo completes its growth within some months and matures at the age of around three years, there is no secondary growth. Bamboo is one of the strongest structural materials used in rural areas of developing countries. Moisture content of bamboo varies along its height location and with seasoning period, which affects treatment behavior of bamboo. It is one of the important factors in deciding the life of bamboo. This paper presents results of experimental investigations made to evaluate the penetration (%) and retention (kg/m^3) of three bamboo species such as Giant (Dendrocalamus giganteus), Sonali(Bambusa gigansula)and Kali(Gigantochola andamanica) with green and oven dry sample . In the present study moisture content, shrinkage, penetration and retention at different height location are worked out. The moisture content varies along the height for green bamboo or at any time after harvesting. The top portions had consistently lower moisture content than the middle or basal at all stages of seasoning. shrinkage on oven dry mass basis decreases from top to bottom.In this study, above mentioned three bamboo species were treated in a commercial wood-treating plant using a full-cell process with Chromated Copper Arsenate (CCA) preservative to target retentions of 20 kg/m^3. Results indicate that among three bamboo species oven dried Kali (Gigantochola andamanica) sample achieve approximately 94.27% of the target CCA penetration with 17.8 kg/m^3 retention .

5.2 Recommendations:

- Generally, a good (chemical) preservation can increase the natural lifetime of bamboos to 15 years in the open and 25 years undercover. Unfortunately, very few data are known about this preservation. Hence further study is needed for this.
- There is a very wide scope for future researchers to explore this area of treated bamboo as it is one of the strongest structural materials used in rural areas of developing countries.
- Wood preservatives can be successfully used for bamboo treatment.Besides development of ecofriendly preservatives based on plant extract, systematic formulations would improve significant result in bamboo artisan sector.

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