FOREST UTILIZATION
FSO's and FBOs

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FOREST UTILIZATION GENERAL

1. Forest utilization

- It is defined as the process of harvesting, conversion and disposal of forest produce.
- It deals with the felling of forest crops, transportation to the market, their processing into various usable commodities and distribution to their ultimate use.
- ItscopescoversnotonlyMajorForestProduce,i.e.,timberandfuel,butalsoallotherforestproducts termed as Non Timber Forest Produce like grasses, bamboos, fruits, leaves, barks, animals, vegetables and minerals.

2. Main branches of Utilization

i. Production of logs that is harvesting and conversion including transportation.

ii. Storage and marketing including seasoning and preserving.

iii. Properties of wood that is wood structure, physical and chemical properties, moisture contents etc.

iv. Uses of timber and non timber forest produces including defects ,derived products, improved uses etc.

What is wood ?

- It is a renewable natural resource used from ancient time for fire ,shelter, defense, agriculture , and other various construction purpose.
- It is of plant origin.
- Lower groups of plant like algae, fungi, mosses do not produce wood.
- Higher groups of plants known as Phanerogams or seed plants comprising the Gymnosperms (conifers), Dicotyledons (broadleaves) and monocotyledons (palms, bamboos and canes) produces wood

CHAPTER I

HARVESTING

Harvesting tools

1. **Axes**

An axe comprises of *axe head*and axe handle. The axe head is made up of a solid piece of iron with a sharp steel cutting edge or blade. The top corner of the blade where the cutting edge begins is called the *toe*, and the bottom corner is known as the *heel*. Either side of the head is called the *cheek . There is a hole at the back of the head* which is called an eye. Axe handle or shaft which is made up of wood is mounted or inserted here. Axe handles are of two types--straight and oval. They have their own advantage and disadvantage.
Based on the use axes have been categorized as :

cutting axes, trimming axes, splitting axes, grubbing axes, tree climbing axes, snow climbing axes etc.

2. **Saws**

A saw consists of a thin, comparatively broad blade or plate of steel, one edge of which is toothed and is provided with one or two handles attached to one or both the ends. They are used for felling, cross cutting, conversion into logs and also if needed for shaping of the wood.
Terms commonly used in connection with saw are:

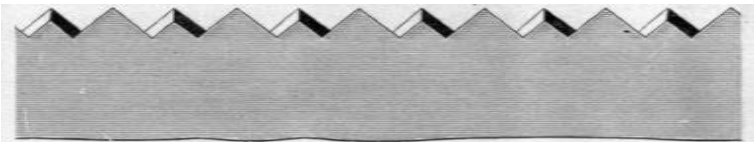
a. Face: Edge of the tooth which faces the cutting direction
b. Back: The opposite edge of the tooth.
c. Space : the distance from tooth to tooth
d. Gullet: The entire opening between two adjacent teeth.
e. Pitch: The angle between the face of the tooth and the line passing through the points of the teeth.
f. Set: The extent to which tooth are bent to either side of the plane of the blade.
g. Kerfs: The width of the saw cut.
h. Gauge: The thickness of the blade.

Types of saw:

Saw may be of different type based on design of the cutting tooth and based on the use.

A. **Type based on the shape of cutting tooth**:

1. Peg toothed saw: This is the most common type of saw. Teeth of the saw are similar to each other and of the form of isosceles triangles. Points and edge of the tooth cuts and loosen the wood fibers. The flanks of the teeth push the saw dust forward through the groove.



3. **Raker toothed saw**: Raker tooth saw has one raker tooth following every two or four cutting teeth. Cutters cut the wood fibers along both sides of the groove. Raker breaks off the fibers and carries them out of the saw kerfs in the form of long narrow chips. The wood noodles roll themselves in the gullets on both sides of the raker teeth and fall out of them outside the stems.

B.Types based on use:

1. **Cross cut Saw**

- Cross cut saws are used for felling trees or conversion into logs.
- -Length, breadth, thickness and shape of the tooth are the characteristics to be considered.
- Length : length of the blade most suit the movement of arms and the diameter to be cut. (140-150 cm/165-170 cm/180-200 cm for 30 cm, 30-70 cm, and 80-100 cm and over diameter)
- Breadth : narrower the blade lesser will be the friction and easier will be the wedge driving.
- Thickness : Thicker blades are stronger and easy to guide but leaves broad kerf and needs lot of energy to saw.

2. BowSaw

- It is used for cutting tree branches or small poles and saplings up to 8inches in diameter but is best for branches which are 6 inches in diameter or less. The bow saw not only cuts in a straight line, but because of the narrow blade and specialty in construction it is useful for cutting curved lines, such as around knots in the wood of trees.

- A modern bow saw resembles a small archery bow with a narrow blade in place of a bowstring.
- A bow saw is handled in a push and pull motion and usually cuts the wood as it is pushed
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3. Pruning saws

- Pruning saws come in a wide variety of sizes and types and are used to prune branches that are more than one and a half inches in diameter.
- The blades of pruning saws can be curved or straight and the teeth of the blades can cut wood on the push or the pull motion of sawing depending on the saw.
- Pruning saws may be straight or curved with handle long orshort.

Maintenance of saws

- Regular maintenance increases the sawing capacity.
- No maintenance means loss of time, waste of energy and wage.

For Maintenance:

- Don‘t allow the rust to appear in the saw.
- Store in dry and dust free place.
- Rub the blade and teeth of the saw regularly with cloth soaked in oil or grease.
- Regularly sharpen the teeth with the help of files.
- Align the teeth in regular interval.

Why saw cuts badly?

- Saw cuts crookedly: When saw blade is not straight
- Sawing is heavy : When saw blade is not clean and is rusty.
- Saw runs easily but cuts badly: When saw teeth are not aligned properly.
- Saw cuts roughly and jumps on the kerf: Joint effect of blunt tooth, rusty blade and wrong or no alignment of teeth.

4. **Power chain-saw:**

It is one man operated and is run by electricity or gasoline. Blades are 50 to 80 cm. in length. Engine is mostly double cycle, air cooled with 1.5 HP to 4 HP strength. Power chain saw has its own advantages and disadvantages over manual saws.

4. Other tools used in harvesting

1. **Bill hook and Canthook:**

These tools are used in dragging, lifting and rolling of logs.

2. **Pickroons:**

This is used for drawing or pulling small logs.

3. **Debarking spade:**

Used for debarking logs.

4. **Ropes :**

Used for tightening, pulling, anchoring

5. **Stem tightener:**

Used for tightening tree trunks to avoid splitting and cracking

6. **Wedges:**

Increases the gap space to make ease for saw movement and axe use. So is used for splitting logs, felling trees**.**

Season of felling

Season of felling is determined by:

(a) Climatic condition of the place

(b) Availability of the labor

(c) Working condition.

- In Terai plains and lower mountains felling season is confined to winter from October to March. In hot months there is danger of fire and water is unavailable. Rainy season is not suitable as roads are not usable and possibility of erosion by log sliding is high.
- In Himalayan region where there is heavy snow in winter felling is done from April onwards and completed before rainy season to avoid erosion by log sledging.
- Felling in hot weather is harmful as to rapid drying of log takes place resulting in splitting and cracking.
- Felling in rainy season is avoided as road condition and labor availability is worse and erosion possibility during logging is high.
- Best suited season is immediately after rain during cold months when trees are not growing and conversion also can be completed before hot weather.

GENERAL Rules of Felling

- Cut as near the ground as possible
- Fell in least damaging direction
- Choose suitable yarding place before felling.
- If required lop the tree before felling.
- Use rope for anchoring and stem tightener to tighten the butt end wherever and whenever required.
- When tree is about to fall, a timely warning is given to all persons by whistle.

- No felling in strong wind or snow or storm.
- Start felling from top of the hill or slope and go down.
- Concentrated felling is better than scattered.
- Felling as well as conversion of felled trees must go simultaneously.

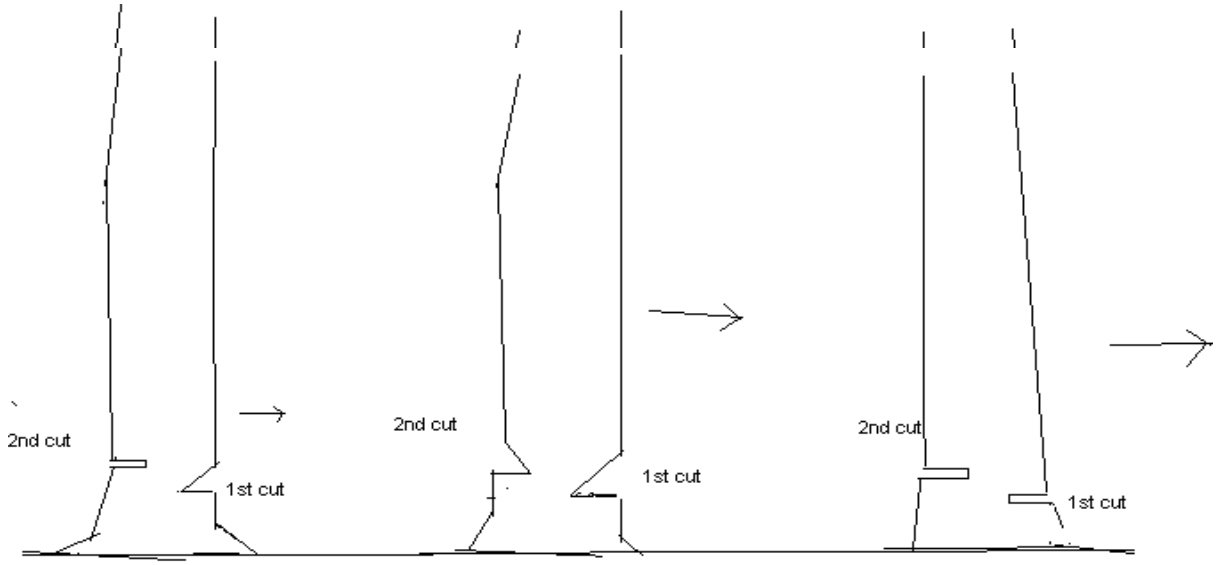
Things to remember during felling

1 Spot cleaning
2 Stump height
3 Roping/loping
4 Direction of fall
5 Fall warning
6 Immediate Conversion into logs.
7 Immediate transport to log yard or depot.

Felling with different tools

4.By power chain saw

4.By power chain saw



1. By Axe and Saw 2. By Axe alone 3. By Saw alone

Conversion of felled trees

- Converting the felled trees into commercial sizes is known as conversionin forestry.
  Principle of conversion:

  1. Minimization of waste and maximization of output.
  2. Minimization in expenditure (Economic factor).
  3. Minimization of difficulties in parts of labors (Ergonomic factor)
  4. Minimization of damage to forest crop and forest roads.
  5. Market demand based conversion product

Shape and sizes of sawn materials into which a felled tree is to be converted depends on the following factors:

I. Demand in the market
II. Availability of the skilled labor
III. Availability of the tools and sawmills
IV. Physiographic conditions of the site.
V. Transport facilities
VI. Possible damage to the forest

The steps involved in the conversion are :

1. Limbing:

trimming off of branches.

2. Bucking:

Main stem is cross cut into logs.

3. Re-sawing :

The logs are then re-sawn into the required sizes. This may be done through hand sawing in the forest or machine sawing in the saw mills.

The different forms of commercial wood available in wood market are:

- Squares and bulks
- Beams, rectangular and scantlings
- Planks and slabs
- Poles
- Firewood
- Pulpwood

Transportation
CHAPTER 2 TRANSPORTAION

- Wood is extremely heavy and bulky commodity in proportion to its value so transportation costs are relatively high.
- Transportation of logs or sawn timber from felling site or jungle depot to the mills or to the consumer consists of more than 60% to 70% of the total cost.
- Prudent choice of transportation means is therefore very important.
- The expense should be kept at minimum.

Transportation of timber from felling site to its final destination may be divided into two parts :

(a) Minor transport

It consists in assembling logs or converted material together at a common point within the forest or from the forest to carry it to the points of loading by major transportation.

(b) Major transport

Transportation from jungle or felling site or collection site to log depot

Factors to be considered during choice of transportation method:

1. Cost involved.
2. Loss and damage to the produce during transport.
3. Total volume of timber to be transported.
4. Size of the timbers to be transported.
5. Nature of the terrain.
6. Available transportation facilities like roads, streams and others.

Types of transportation.

Types of transportation may be divided into three categories.

1. Land transport.
2. Water transport.
3. Overhead transport.

1. Land Transport

a. Carriage by men:

On steep slopes small and medium sized timbers, like sleepers, small poles and

posts, fuel wood pieces etc. are carried by men on their shoulders and backs to the collection site. Only trained persons are employed for such load carrying job. It is an expensive and labor consuming method.

b. By animals:

In plains and semi-hilly areas depending upon the availability of types of animal bullocks, buffaloes, camels, horses, elephants, mules etc. are used for dragging, rolling or skidding logs.

c. By carts:

A cart has two low wheels and is hauled either by single bullock or a pair of bullocks. Such carts have an advantage of easy mobility to go directly to the felling areas. Timbers are loaded in the cart manually and animal hauls the cart to the destination.

(d) Sliding and skidding :

Sliding is sometimes used in hilly grounds. In this method logs are allowed to slide down the hills by their own weight. Because of the extent of damage to the forest and the ground itself this method is not recommended.

Skidding or dragging of logs are sometimes done by animals or tractors. But extent of damage in the ground and the logs is very high in this method so is avoided wherever possible.

(e) Trucks, tractors, railways:

a. Railways or tramways.

Establishment, operation and maintenance of railways and tramways is economically feasible only when a very large quantity of timber is required to be moved for a long period of time. Railway lines are laid on wooden sleepers and the wagons are drawn by a small steam or diesel engines.

b. Trucks and tractors.

These days timbers whether within the forest or outside the forest are moved by trucks, lorries and tractors. Advantages of this form of transport are that the vehicles may drive right up to the felling sites, eliminating the need of skidding and sliding and these vehicles can collect and transport material over a scattered area. They can also collect the debris like lops and tops, barks etc which would otherwise be left behind in the forest. However, construction and maintenance of roads requires a heavy investment.

2. Water transport

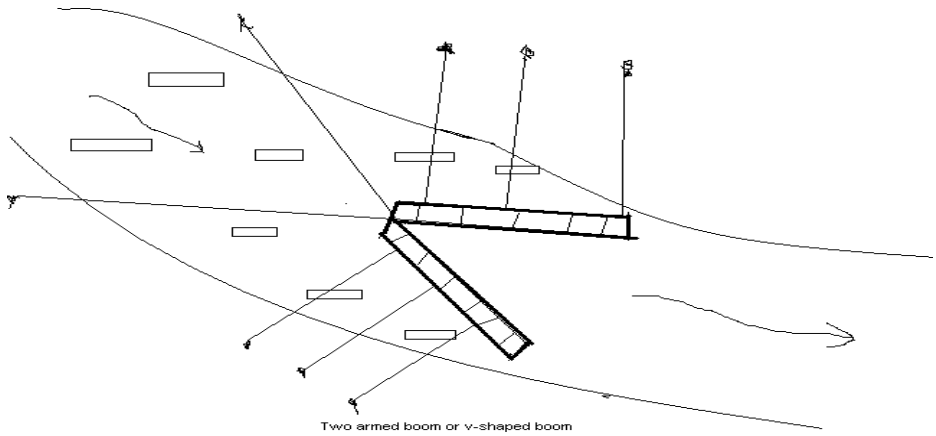
a. **Floating**: Timber is floated down rivers and streams. Material to be floated should be light and water course should be wide and deep enough for the free movement of the timber. Curves in the bend of the river should be round so that timbers do not get stucked. Telescopic floating involves the transport of the timber down narrow streams having steep slopes and rocky bends. A rough chute like structure is made as the flow of water may not be sufficient to push the timber down the water course.

b. Rafting

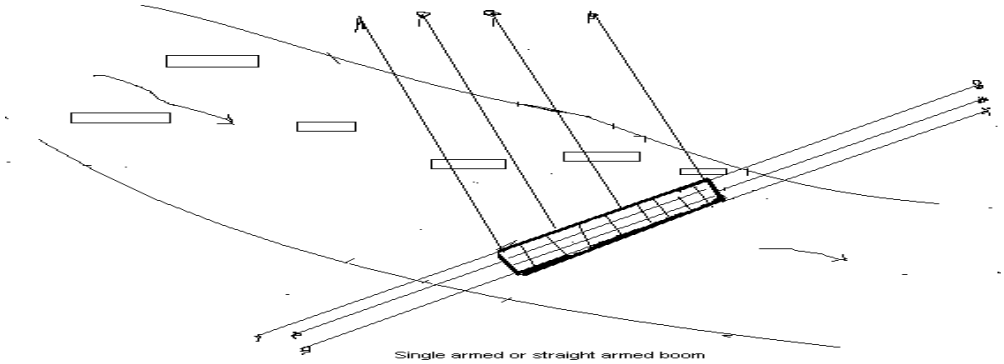
- Raft floating is done along big rivers free from rapids and other serious obstructions.
- Logs of timber and bamboos are tied together to make temporary rafts which are then floated down rivers.

c. Boom

a boom is a sort of barrier across the river made for arresting the floating timber. They are made of logs or sleepers of timbers bound across the river against its direction of flow. Boom may be of straight shape stretched from one bank of river to other bank or may be of V-shape pointing upwards the flow of river.



Two armed boom or v-shaped boom



Single armed or straight armed boom

Loading and unloading by manual and mechanical systems:

Choice of manual or mechanical system to load and unload the timbers in trucks and tractors depends upon

- Volume of timber to be handled.
- Availability of skilled labors.
- Availability of suitable machine
- Cost involved.
- Terrain where work is to be done

Factors to be looked during loading and unloading.

- Ergonomy - Safety - Economy & Available time.

CHAPTER 3
Structure of wood

1. Tree parts and their function

a. Root - anchorage, water and mineral absorber
b. Trunk – strength, carries w & m to crown through its outer portion
c. Crown – gives characteristic shape, converts water, nutrients and carbon dioxide into useable food materials reqd. for the growth of the tree

2.Food movement
Food materials move through inner bark or living bark of the tree to the growing regions .

3.Tree growth and wood formation
As a result of the activity in the growing regions tree grows or increase in size in two ways

a. height or apical growth confined to buds (primary growth)
b. radial or cambial growth confined to cambium (secondary growth)

4.The Cambium layer
It is a thin continuous layer of meristematic tissues extending throughout from root to top between the bark and the wood.

It is a zone of actively dividing cells which, during the growing season, cuts off new cells both externally and internally.

Those cut off on the inside go to form the wood while those cut off outside make the barks .Every year **cambium** goes on adding woody tissues on the inside and some bark on the outside, and the tree consequently increases in girth.

Gross structure of wood

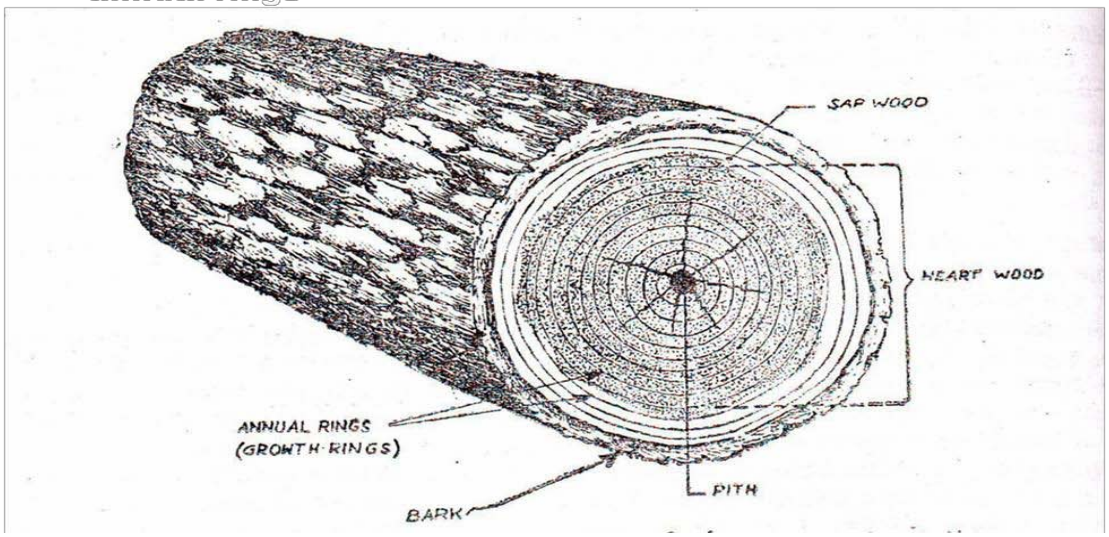
It is the structural features of the wood that can be seen with our naked eyes it can be easily studied on the cut end surface of the log or on the stump of a newly felled tree.

Cross cut of a pine log showing sap wood, heart wood, bark, pith and annual rings:

A. Gross structure or gross features of wood

Cross section of a log

Showing sap wood, heart wood, bark, pith and annual rings



1 **Bark** : Outer zone, rough, corky consisting of dead and dying cells (fissure/cracks in shorea,chirpine)
Inner zone, smooth, moist actively associated with conduction and storage of food material required for the growth
Thickness, color and appearance are different in different species

2 **Pith** : core wood at the center of the log. May be round, oval, triangular or squarish (about 0.6 cm in diameter)—chambered in juglan—squarish with concave side inteak.

3 **Growth rings (Annual rings):**
Annually grown wood ring around the pith is called annual ring. In temperate

region where there are two distinct growing season the wood ring is indicative of age.

In Tropical region where there is no distinct growing season growing is a continuous processes and hence annual wood input rings are not truly indicative of age. So it is called growth ring.

Rings are prominent in conifers like chir, deodar and in broad leaved species like mulberry, teak, tooni etc. Many species like Sal, gurjan, jamun, mango do not show any growth rings as growth is more or less constant throughout the season.

4 **Sapwood and Heartwood:**

Woody cylinder mass around pith and inside bark of a tree has two distinct zones :

1. The outer-light colored portion is known as‗sapwood' which is composed mostly of living cells and is concerned with conduction of sap that is rich in starch and other food material. It is not durable, susceptible to insect and fungal attack

2. The inner-darker colored portion is heartwood, It is dead and does not take any active part in the life of the tree except giving rigidity. Heartwood is durable- composed mostly of tyloses with gums, resin, tan in and other extract which serves as natural preservatives.
Abies, Picea, Mangifera, Bombax and Ficus —no color difference.

5 **Early wood and Latewood**:

Wood formed in the early part of the growing season or wood towards the inside of the growth ring is called ‗early wood'

Wood that is formed in the later part of the growing season or the wood that is towards outside of the growth ring is called ‗latewood'.

In temperate region it corresponds to the spring and summer season so is called ‗spring wood' and ‗summer wood'.

They differ in structure and texture. The greater the difference- more prominent is the growth ring'

6 **Grain and Texture**:

Grain in wood refers to general direction of alignments of the cell. Depending upon the actual alignment of the wood elements in relation to the axis of the tree the grain may be straight, spiral, cross, intertwined, interlocked, wavy, irregular etc (interlocked in sal). Nature of the grain affects the strength , seasoning, and other properties of the wood and has great significance in timber utilization.

Texture is nothing but size of the cell. Depending upon the size of the cell it may be coarse and uneven as in mangifera, albizia, and termanalias fine and even as in Santalum, Adina, gardenia etc.

Minute structure of wood

It can be studied only under compound microscope.

Wood is made up of minute compartments of cells, each with a distinct wall of its own, which consists mostly of cellulose and lignin.

Wood has three function in nature

a. conduction b. mechanical support and c. storage

Depending upon their function and structure the various type of cells that go to make up wood are classified as vessel, trachieds, parenchyma etc.

The size, proportion and arrangement of different kind of cells give raise to different patterns in the wood.

This minute structure is responsible for giving unique qualities to wood like paint holding, driving easiness for nails and screws, absorbing preservatives, swelling and shrinkage, twisting and warping, combustibility, susceptibility to decay and damage etc

Because of the air and moisture trapped in the cell cavities, wood is a poor transmitter of heat, sound and electricity and acts as efficient insulating material.

1. **Pores or vessels**

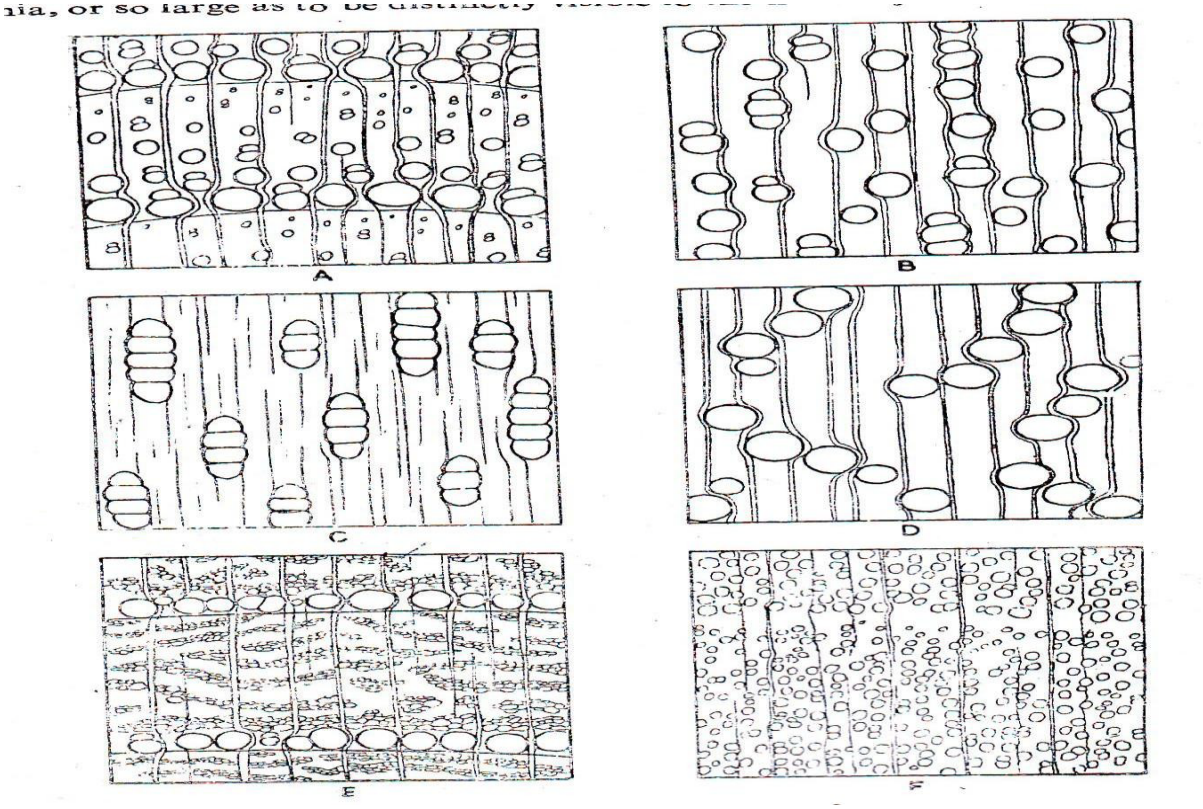
   They are vertical series of cells with open ends placed one above the other forming continuous tube running in the direction of the long axis of the tree. Their main function is to conduct water & moisture from soil to the crown.

   On longitudinal section of the timber the vessels look like a fine scratches or grooves. When cut across, they appear on the surface of wood as small, circular

openings or holes and are so called ‗pores'.

Arrangement and size of pores :

A. ring porous B. diffuse porous C. long radial multiples D. oblique groups E. latewood pore in cluster F. minute pores



Porous and non-porous wood or softwood and hardwood:

Occurrence of pores or vessels is a constant feature of all broad leaved species and hence the wood of the broad leaved species is described as ‗porous'
Such vessels or pores are entirely absent in the conifers and hence is called ‗non-porous'

In the trade non-porous woods are usually referred to as ‗soft woods' while porous woods are known as ‗hard woods'.

Softwood or hardwood have no relation to the relative hardness or softness of the timber but merely refers to broad leaved species and conifers.

b. Ring porous and diffuse porous :

Based on the arrangement of pores, porous wood can be divided into two main groups – ‗ring porous' and ‗diffuse-porous'

Early wood has large pores than late wood and form a distinct belt at the beginning of the growth ring (teak, mulbary, toon and ash). These woods are classified as ‗ring porous'

But majority of indian woods don't have difference in pore size of early wood and late wood and hence are classified as ‗diffuse-porous' (sal and haldu).

2. **Fibres:**

   Vertically aligned, narrow, elongated and thick-walled cells with pointed tapering ends, which make up the bulk of woods by weight in most of the hardwoods.

   Its main function is to give mechanical support to the tree and like vessels they are absent in the non-porous woods or conifers or softwoods.

   Their darker colored ground mass in which vessels and other light colored wood elements are arranged give rise to various patterns. Like vessels fibres also are generally absent in conifers.

3. **Tracheids**

   They are the main longitudinal elements of conifers or non-porous wood in which pores (vessel) and fibres are absent. Their function in conifers is to conduct sap and give rigidity to the tree.
   Tracheids in wood formed in the latter part of the growing season have thicker wall and hence gives rigidity to the coniferous trees like fibres does to the broadleaved trees. Trachieds in wood formed in early growing season have large lumen and thin cell wall so they conduct moistuer and nutrients from soil to crown in conifer trees as does vessels in broadleaved trees.
   Thick walled trachieds of the late wood appears darker, denser and compact as compared to trachieds of early wood.This difference in color of traheids give rise to the prominent growth ring.

4. **Wood parenchyma or soft tissues**
   They are Short, rectangular or brick-shaped cells, with comparatively thin walls and simple pits, which function is storage and conduction of food materials.

They are oriented in the same direction as fibres and vessels, with their longitudinal axis parallel to the grain.

They are present in both porous and non-porous wood but are poorly developed in latter.

Individually they are of no importance but collectively they form various patterns which are very important in the identification of timber.

Parenchyma distribution commonly met with are :

a. Apotracheal types :

They are independent of the distribution of the pores. They may be

1.Terminal or initial
arranged in continuous line or narrow band which may be formed either at the beginning or at the end of the growing season. They are usually lighter in color than the background. Clearly demarcate the growth ring. In well develop stage they are visible to the naked eye as in champ, satinwood. While in others, they may be visible only under lense like in termenalias.

2. Diffuse
Occur as isolated cells or small groups of 2-3 cells throughout the ground mass of the wood. In dillenia and haldu these parenchyma looks like scattered light colored dots under trained eyes.

3. Reticulate or net like:
Parenchyma cells in some wood form more or less evenly spaced, tangential lines, which together with rays give rise to a characteristic pattern resembling almost like a meshes of a net. Parenchyma lines may be broken or continuous, close or widely spaced, thick or thin giving rise to various reticulate pattern. In ebony and pali (palaquium spp.).

b. Para tracheal types :

1. Vesicentric
Here the soft tissue form a narrow but complete sheath of more or less uniform thickness around the pores. These sheath are distinctly visible under eye lenses also as in babul (acacia nilotica or arabica)

2. Aliform or eyelet type

The soft tissues forming uniformly thick sheath around the pores some time

extend sideways as wing-like lateral extension giving eyelets like design, it is called aliform or eyelet type. (characteristic of kokko, acrocarpus, mango).

Aliform and vesicentric type of soft tissue may be found in same timber also. Eyeletsconnectedtogetherare_aliformconfluent‘(characteristicofsissooand sandan)

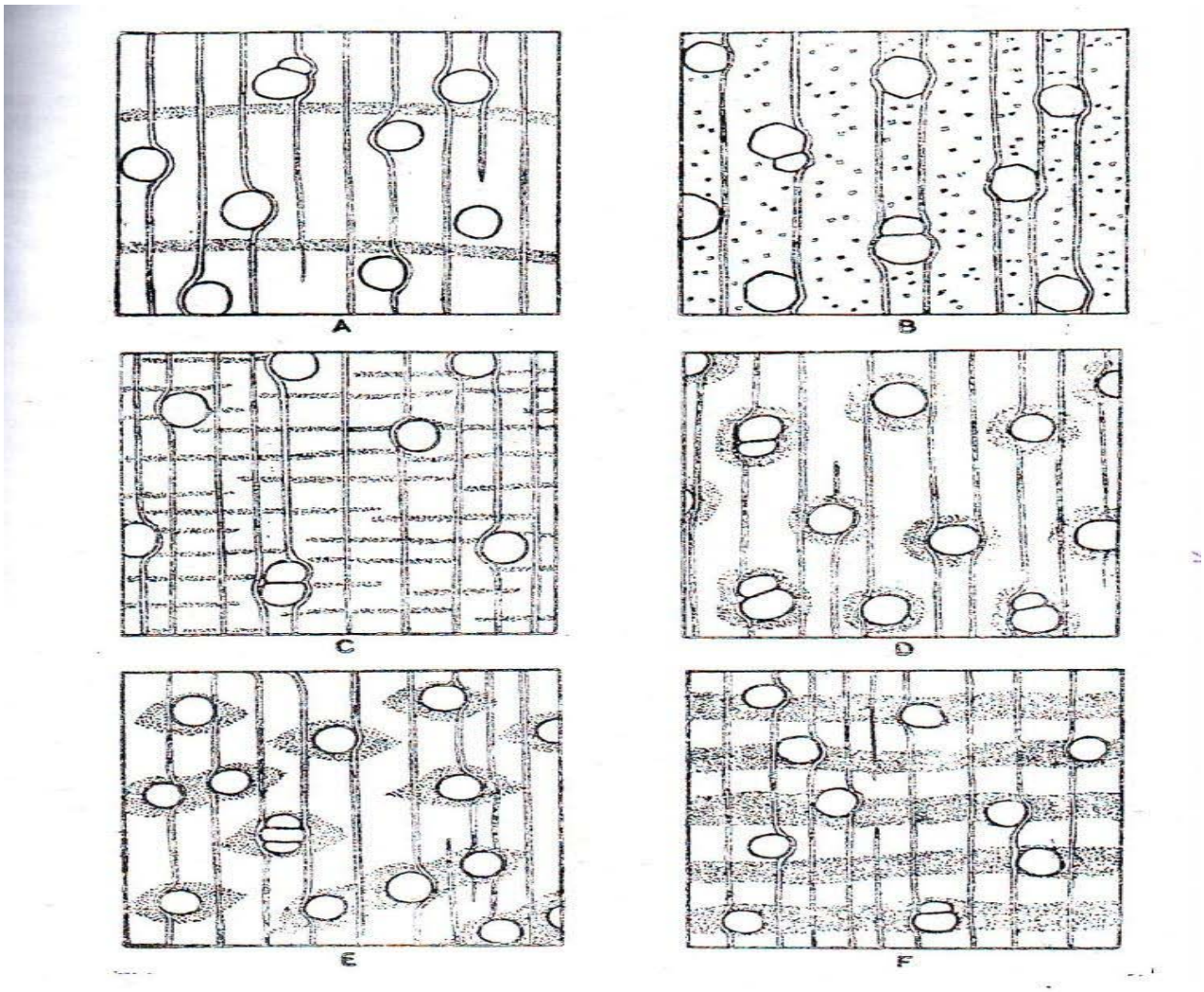
3.Banded

When Parenchyma tissues are arranged in continuous tangential bands alternating with fiber layers throughout the growth ring it is called banded.

Bands may be broad or narrow, straight or wavy, confluent or independent of pores. Such pattern is conspicuous in Butea and Ficus.

Parenchyma distribution :

A. terminal or initial B. diffuse C. reticulate or net like D. vasicentric E. aliform or aliform confluent F. banded.



5. **Pith flakes**

It is irregular batches of soft tissues formed as a result of the injury to the cambium due to insect attacks. On the broad face of wood they give different look than the natural color of the wood. Not much of a problem. Some species form more pith-flecks than other.

6. **Rays:**

They are groups or plate of horizontally-oriented parenchyma cells. They run radially from pith to the bark. On the cut end of the log they appear as light colored lines radiating from the center.

Some of them extend from pith and are known as primary, while others which arise at various distances from the pith in between the primary rays are termed secondary rays.

On the tangential surface of the wood they appear spindled shaped bodies somewhat darker than the background , while on the radial face they look like ribbons running across the grain.

May be broad as in oak, beech, high or narrow and low as in all conifers, termenalia, lagerstroemia, ebony.

7. **Ripple marks:**

They arise from rays of more or less uniform height arranged in horizantal rows or series, making equidistant wavy lines running at right angles to the grain as in bijasal (Pterocarpus Spp), kanju (Holoptelia Spp). Satinwood (Chloroxylon swietenia). Sometime longitudinal parenchyma and fibers may also show a corresponding horizontal striation along with the rays making the ripple marks very conspicuous.

8. **Intercellular canals or resin canals or gum ducts :**

They are long tubular cavities found in wood which serve as repositories for waste products of metabolic activities like resins and gums. They may run vertically or horizontally. And are found both in porous and non-porous wood.

CHAPTER 4
Density and moisture of wood

4.1. Introduction :

In economic utilization of timber inherent qualities of timber like appearance, color, moisture content, density and specific gravity plays major role.

Its response to sound, electricity, heat, light, water, and other liquids etc. along with its response to the external mechanical forces or chemical reaction with other compounds is governed by these qualities.

So these qualities dictates its place of use like decorative use, insulating use, musical use, medical use, use in light or heavy construction.

4.2. Density and Specific gravity of wood.

1. Color:

Different species of wood has different color. Color of the wood darkens on exposure to sun and weather due to chemical changes that take place on the exposed surface of the wood. There is color difference in heartwood and sap wood.

2. Lusture:

It refers to the degree of reflection of light from the walls of the cells. It varies with structure of cell wall, angle at which the wood surface has been cut, and the angle of incidence of light.

3. weight of wood:

The weight of wood is the total weight of all the matter it contains. That includes wood substance, extraneous matter, and moisture present in the water.

4. Density of wood:

The density of wood is the weight of a unit volume of wood. It is expressed in terms of Kg per cubic meter (d=m/v). In wood it varies with the amount and volume of air space (cell cavities) present inside the material.

5.Specific gravity of wood:

Specific gravity of wood is the ratio of weight of the wood to the weight of an equal amount of water at a given temperature usually at 4 degree C . It is expressed in terms of dry or oven dry basis.

$S=Wo/Vg$ where $Wo = Wm/1+m/100$.

Specific gravity of cell wall substance for all wood is approximately 1.53.

Specific gravity of the wood can be increased by compressing it. Increased specific gravity means increased in strength of wood.

Variation in specific gravity

The weight and volume of a piece of wood can be determined under three different condition namely oven dry, air dry and green. Accordingly there will be nine different values of specific gravity on which the symbol ‗o', ‗a', or ‗g' correspond to.

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- Oven dry weight and volume in oven dry condition which is denoted by symbol with suffix‗ oo'.

- Oven dry weight and volume in air dry condition which is denoted by symbol with suffix‗oa'.

- Oven dry weight and volume in green condition which is denoted by symbol with suffix ‗og'. This one is known as standard specific gravity.

  Corresponding to the density of wood specific gravity of wood varies with species, growth condition of the tree within same species, and location of wood in the same tree.

Location of water in wood

Wood isa hygroscopic substances and hence contains varying quantity of water both in freshly felled condition and in air- dry condition.

Water held by wood causes shrinkage or swelling, change in strength properties, change in electrical resistance, dielectric and thermal properties, fungal and insect attack. It indirectly affects adhesion of glues and finishes.

In green wood, water is located in the voids of the microscopic cell cavities and in the finer sub-microscopic voids of the swollen cell-wall, which are transient in nature.

Water contained in the cell cavities is free from the action of intermolecular attraction of the cell-walls. It is held only by capillary forces. Water held in the cell cavities by such capillary force is termed as free water.

Attraction of wood for water arises from the presence of free hydroxyl (OH) in the chemical structure and arrangement of the cellulose molecules within the cell-wall. Electrically, hydroxyl groups are negatively charged. Water is a polar liquid consisting of a negative OH fraction and positive H fraction. The free hydroxyl

(OH) groups in cellulose attract and held water by bonding with positive hydrogen fraction of the water. Water held in the cell-wall by such bonds is termed as adsorbed, hydroscopic or bound water.

Nature of water in the wood

- Cell-walls are mesh-work of strand-like sub-microscopic structural units, called micro-fibrils, which are in reality aggregates of long chain molecules of cellulose. Long chain molecules become alternately parallel and non-parallel in their orientation within micro-fibril, giving rise to alternating crystalline and amorphous zones.
- The OH groups on the long chain molecules of cellulose in the interior ofthe crystalline zone are engaged in cohesive cross-bonding between adjacent cellulose chains and are therefore not available for adsorbing water
- The major portion of the bound water is taken up in the amorphous zone of the cell-wall and only a small portion on the peripheral surfaces of the crystalline zone.
- The water in these two zones is absorbed in poly molecular or mono molecular layers.
- The cell-wall swells in order to accommodate these layers of absorbed water.

Moisture content of wood

Amount of water present in the wood is expressed as a percentage of its oven-dry weight and is termed as moisture content.

Maximum Moisture Content

Moisture content of the wood is at its maximum when the cell walls are completely saturated and the cell cavities are filled with water.

Maximummoisturecontent_M'isexpressedbyM=(1/Sg-1/1.46)*100,whereSg is the specific gravity of the wood on the oven dry weight/swollen volume basis.
1.46 is the sp gr of the wood determined by helium displacement. M is as high as 64% for heavy axle wood (spgr 0.757), 11.2% for moderately heavy teak (sp gr 0.554)

Moisture content of wood in living trees varies in quantity in species to species from 30% to 200%. (in bombax upto 150% , in teak and sissoo 80% and in heavy wood like axle wood it is about 50%)
Within same sp-- from place to place of growth and difference in condition of growth.Within a tree position to position of wood in it (branches or stump, sapwood or heartwood etc.)

14. Equilibrium Moisture Constant(EMC):

Water content in the wood exerts a vapor pressure of its own. It is determined by

the size of capillaries filled with water at any time. If the water vapor pressure in the ambient space is lower than the vapor pressure within the wood, desorption takes place. Large capillary empties first and then smaller ones. When pressure inside and outside becomes same desorption stops. The amount of moisture in the wood at this stage is in equilibrium with the water vapor pressure of the ambient space and is termed as

15. Determination of moisture content

1. Oven dry method:

$$Mc = \frac{\text{wet weight} - \text{oven dry weight}}{\text{oven dry weight}} * 100.$$

(Sample of 2.5 cm*5cm*5cm piece of wood heated to 100 to 105 degree centigrade)

2. Distillation method:

In oven dry some volatile oil also distill off giving falls higher value of moisture content. So wood is converted into small chips and boiled with organic liquid (toulene) not mixable with water and having boiling point higher than water.

3.Electric moisture meters:

portable, easy to operate, gives direct and quick readings. There are two types of Electric moisture meter. They are:

a. Electrical Resistance Meter
b. Capacity Resistance Meter
(dielectric constant and power factor difference with moisture content)

Factors influencing strength properties of wood

It can be classified into two broad categories:

1. Growth condition of timber and their inherent characteristics over which there is no control at the time of test

2. External factors influencing the strength of wood for which there can be a control :

Inherent characteristic factors influencing the strength of timber:

1. Soil, climate, and locality

2. Age of the tree
3. Position of wood in the tree
4. Rate of growth
5. Season of felling of tree
6. Natural and plantation grown trees
7. Live versus dead timber
8. Natural twist in the tree.
9. Specific gravity
10. Other growth factors

External factors influencing the strength of timber:

External factors can be divided into two categories.

1. Condition of timber at the time of selection like:

a. Moisture content
b. Temperature (increase at low, decrease at high)
c. Preservative treatment(?)
d. Defects (grain angle-strength highest at 0 and lowest at 90, knots, shakes and splits, pith , decay and sap stain

2. Method of use or test of wood materials

a. Transportation and storage technique
b. Using technique
c. Type and extent of stress applied
d. Size and shape of specimen or piece being used
e. Extent of damages during handling

CHAPTER 5
WOOD SEASONING

What is seasoning?

- Seasoning of timber is a process of drying it to a suitable moisture contents so that it is in equilibrium with the prevailing atmospheric pressure.

- A proper and efficient seasoning process is designed to achieve controlled drying of timber to the required moisture content, in the shortest possible time with minimum damage to it(degrade).

Why seasoning ?

- Essential for economic and rational utilization of timber resources.
- To reduce loss of wood through surface cracking, splitting, warping etc in storage, transit and services.

- To stop unnecessary shrinkage, swelling, decay, mould growth, strength deterioration.

- To improve several wood properties like insulation, thermal conductivity, electric resistivity etc.

Importance of seasoning

- An important objective of seasoning timber is to dry it to the EMC before use, so that gross dimensional changes through shrinkage are eliminated.
- To provide dimensional stability to the timber products.
- To avoid losses through cracking, splitting, warping etc. (which are liable to occur while using green timber under uncontrolled climatic condition).
- The organisms which causes decay, stain and mould formation don't thrive below 20% moisture content. Most of the pest thrive in green lumber only.
- Seasoned wood is less susceptible to decay and damage than not seasoned one.
- Seasoned timber is lighter and hence the transportation and handling costs are reduced.
- Seasoned timbers are stronger than the green timber in most of the strength properties.
- Seasoned timber absorbs preservatives more easily.
- Seasoned wood-work finishes and glues better. So also paints and varnishes last longer in seasoned wood.
- Seasoning improves electrical and thermal insulation properties of wood significantly.

General principles of Seasoning

- Tendency of its outer layers to dry out more rapidly than the interior. If the outer layers dry much below fiber saturation point while inner wood is still saturated, stresses called drying stresses are set up. If this stresses exceed strength of the timber, wood tissues rupture, rendering timber to split and crack. This is a great problem in seasoning timber.
- So general principle of seasoning is to control the drying defects by maintaining a proper balance between the rate of evaporation of moisture from the surface and the rate of outward diffusion of the moisture from the interior of the wood.
- Surface tries to reach EMC with drying air while interior wood moisture content is still far up. Temperature and RH of drying air is maintained sufficiently high in the early stages of drying to limit severity of drying stresses to avoid splitting. The extent to which such control of drying condition is necessary depends upon species to species and size to size of timber.
- The rate of drying wood is governed by interaction of external drying conditions like—temp, relative humidity, rate of air circulation, and the rate of moisture diffusion within the wood.
- Prompt seasoning of wood immediately after felling and conversion of trees results in significant upgrading of the raw timber.
- So all timbers –no matter whether they belong to primary species of teak class or secondary species like mango, jamun etc. whether they belong to naturally durable class like sal and Deodar or non-durable class like mango and chir, and whether they consist of heartwood or sapwood-required to be seasoned
- Seasoning enables substantial long-term economy in utilization by minimizing replacement, and rationalizing the utilization of our timber resources.

Factors related to seasoning

A. Factors that can be controlled
   - Temperature
   - Relative humidity
   - Air circulation

B. Factors that cannot be controlled
   - Nature of wood species
   - Initial moisture content of the wood
   - Grain direction in the wood
   - Thickness of wood

5.2 Method of seasoning

There are two methods of seasoning:

1. Air seasoning.

2. Kiln seasoning (dry air, water vapor etc)

1. Air seasoning

a. Site, shed and foundation:

As far as possible all shed should be east-west oriented, well ventilated, roof raised to sufficient level, well drained pucca floor, raised ground against surrounding. Generally three types of shed. are used for seasoning woods.

1. Shed type 1

Roof with walls on all four sides. (for refractory hard woods like termenalia, sal in hot and dry climate).

2. Shed type 2

Roof and three walls except in North (for moderately refractory timbers like teak, sisso , tooni etc).

3. Shed type 3

roof but no side walls (for drying moderately refractory woods in very moist climate and refractory woods in dry and hot climate).

Wood stacking methods:

Since seasoning is a process of controlled drying of wood , it is necessary to stack the timbers to be seasoned to control the rate of drying. There are two ways of stacking.

1. Horizontal stacking. And Vertical Stacking

-***In horizontal stacking*** timbers are stacked with the help of crossers or battens, while in ***vertical stacking*** different kinds of stands or vats are used.

In both the cases if wood is of refractory in nature air circulation has to be decreased in hot and dry climate. If wood is of non refractory in nature good circulation of air has to be maintained.
Shape ,size and types of the stacking depends upon the dimension of timber and type of seasoning being carried out.
(Logs, Planks, Beams, Poles (transmission poles, fencing poles), Railway slippers).

Seasoning in Kilns:

- It is a process of drying wood by the use of artificial heat.
- Artificial control of RH and air circulation are provided at various stages to achieve efficient drying.
- Timber is stacked in chambers, called—seasoning-kilns .They are fitted with equipments to control temperature, relative humidity and circulation of drying air.

Types of Seasoning Kilns

1. Progressive kilns.
2. Compartment kilns.

Constructional design of kiln and their mode of operation:

Kilns differs widely in their construction and mode of operation.

a. Constructional material

Different construction material can be used depending upon availability and requirement like brick masonry, hollow cement concrete slabs or tiles, sheet metal in a double walled construction with thermal insulator in between etc.

b. Mode of heating
(fuel gas from a furnace fired by oil or wood waste, electrical heating, steam heating is most popular– pressure up to 5.6 kg per sq. cm.).

c. Mode of Humidification
(controlling is possible)

d. Mode of Air circulation

Types of kilns based on mode of heating: (forced air circulation kilns, natural air circulation kilns).

a. Steam heated kilns:
Over head internal fan reversible air circulation seasoning kiln.

b. Furnace kiln
Indirectly-heated with internal fan.
Indirectly- heated with thermal circulation.

c. Veneer dryer kilns

d. Hot-air drying kilns

Type of timber:

1. Highly refractory (sal,karma),

2. Moderately refractory (sissoo,teak),
3. Non-refractory wood (simul,gutel)

Air seasoning vs Kiln seasoning:

Following factors are looked for comparing advantage and disadvantage of Air seasoning and Kiln seasoning.

- Initial investment
- Skill needed
- Sizes and quantity of timber to be seasoned
- Time required
- Yard space required
- Quality of drying

End-coatings :

Rapid drying of logs and sawn timber is reduced by end coating the pieces with certain chemicals like oil paints, bitumen paints, coal-tar paints, paraffin wax etc.

Drying is faster along the grain and is slower across the grain. Log ends are along the grain so coating the end with chemicals means slowing the process of evaporation. Slow evaporation or drying of log means almost no damage to logs

CHAPTER 6
Defects in timber

There are two kinds of defects in timber. They are :

A. Natural defects

1. Knots

a. According to size:
pin(1/4‖), small(3/4‖), medium(1.5‖), large(more than1.5‖)

b. According to form:
Round knot, spike or splay knot

c. According to condition:
Live knot, decayed or unsound knot, loose knot, dead knot, pith knot, enclosed kn
…

2.Shakes:

a. Star shake
b. Ring shake

3. Grains:

Cross grain, diagonal grain, spiral grain, interlocked grain etc.

4. Reaction woods.
5. Compression failure.
6. Resin pockets and resin streaks.
7. Bark pockets.
8. Chemical stains.
9. Constriction due to climbers.

B. Other than natural defects:

This type of defects are incurred during subsequent treatment of felled timber

a. During seasoning

* warping
* checks, splits and shakes
* case-hardening
* collapse

b. During conversion and wood working:

* Boxed heart
* Imperfect grain

c.Defects resulting from activity of external agents

* Fungal defects
*Insects and other animals caused defects.

CHAPTER 7
COMPOSITE PRODUCTS AND THEIR MANAFACTURING PROCESSAND APPLICATION

7.1 COMPOSITEWOOD

Definition and importance:

Composite wood is a general term for built-up, bonded products, consisting wholly of natural wood e.g. plywood, particle board etc or of wood in combination with other materials like metals, plastics, grasses etc

It overcomes the defects present in natural wood like growth defects, hygroscopicity defects, lack of strength balance due to anisotropy, lack of strength in compression and shear, non uniformity etc.

Composite wood products helps in utilizing waste wood and wood of inferior species.

They are developed from relatively small pieces or by treating and modifying wood at hand by means of pressure, heat and chemicals.

FORMS OF COMPOSITE WOOD

1.Plywood*

2.Laminated wood

3.Core boards

4.Sandwich boards

5.Fiber boards

6.Particleboards*

7.2 PLYWOOD

History :

: - Use of veneer dates back to 1500BC
- Used in Europe in late 17th century for ornamental purpose
- Used for tea-chests in China in 18th century for tea-trade
- Commercial production started in Russia with establishment of first plywood factory towards1880s

What is it ?

It is a glued wood construction built of veneers in a way that grain of each veneer is at right angles to that of the adjacent veneers in the assembly. This method of assembling wood component is referred to as –cross-bonding construction..
Outer plies in plywood panel are called faces, or face and back. Center plies are called core. Core may be of veneers only or various combination of veneers and timbers.
Plies in plywood may vary as regards numbers, thickness and kinds of wood. Plywood consists of any odd number of plies. Simple one is three piled. In panels having more than three plies the layers between the core and the face or back are called —crossed bands‖.

ADVANTAGE OVER SOLID WOOD

Cross banded plywood has many advantage over solid wood like..

a) It has dimensional stability
b) It has strength distribution in both the direction
c) It has no tendency to split
d) Can have big size
e) Can be molded to various shapes
f) Can be made waterproof.

Balanced construction:

- Plywood tends to warp as a result of stress caused by dimensional change.
- It is overcome by balanced construction. This construction consists in arranging the plies about the core in such a way that for each plies there is an opposite, similar and parallel plies.
- Plies are matched with respect to species, thickness, original moisture contents and type of veneers.
- Plywood are constructed with odd number of plies. Balanced construction is more important in thin veneers than in thick veneers.

Manufacture of plywood

1. **Location of mill for plywood production:**

Volume. of round wood required. For plywood mill is 2 to 2 ½ times the projected production of plywood volume. About 60% of log gets wasted during manufacturing process..
To ensure availability of enough raw material and to avoid transportation cost mills need to be located as near to the source of wood as possible.

2. **Preparing the veneers**

First logs are debarked; knots and bends are cleaned off and cut to the suitable

sizes to fit in the machine. They are then put in the water tanks or ponds to get soften. Softened pieces of logs are then mounted in the rotator peeling machine to get wood peels 1.25 mm to 1.5 mm in thickness. Some logs are sliced in slicing machine to get 0.6mm to 1.25 mm thick slices. Thus obtained peels or slices called veneers are trimmed according to requirement in trimming machine and joined together by gluing on a splicer machine.

3. Drying of veneers

There are different types of Veneer dryers. Some are roller type, some platen type and some band type. Prepared veneer in step second above is dried in one of these machines under controlled temperature. and pressure

4. Mixing and spreading the glues

In early days animal glues and starch glues were used which later were replaced by blood albumin and protein glues.

These days synthetic glues like urea-formaldehyde (UF), phenol formaldehyde (PF) etc. are used. Synthetic glues are more resistant to water and organism causing decay, and hence are preferred.

According to durability, uses and properties glues can be classified in a number of ways like..
Thermosetting glues, thermoplastic glues, weather-proof and weather-resistant glues, gap-filling glues and contact glues, etc.

Glues are carefully mixed with correct proportion of the ingredients by weight (when ingredients are solid) or by volume (when ingredients are liquid).

Glues with short working life are prepared in small batches. Even for having long working life it is good to prepare small batches and to mix frequently.

Veneers are coated with prepared adhesive by means of a spreader. Scrapers or other such devices regulates the thickness of the glue.

The core or cross- bands are coated on both the faces if the glue is liquid type. The amount of glues spread is described in terms of quantity of glue in Kg per 1000sq m.

Phenolic resin glues are available in the form of a thin film. The film is cut to required size and inserted between the sheets.

Time interval between the spreading operation and the application of full pressure upon the plywood panel is known as the —assembly time‖.

5. **Pressing**

The glue-coated veneers are assembled in proper order and subjected to pressure.

Depending upon the type of glue the pressing is done either at room temperature (cold pressing) or at high temperature (hot pressing at 100 to 150 degree centigrade).

All the pressing is done in hydraulic press using pressure of 7 to 10 kg per sq cm for low density wood, 10 to 14 kg per sq cm for medium density wood, and 14 to 18 kg per sq cm for high density wood.

6. **Conditioning of plywood panels.**

Assembled veneers that is the plywood formed in step 5 is then conditioned in conditioning chamber to bring down the moisture content to 12 % level.

7. **Trimming, sanding and storage.**

Conditioned Ply woods are then trimmed by cutting unnecessary parts. It is then sanded for
smoothness and stored in dry and clean place.

Laminated board

1 It is a built –up product made of wood layers – called laminae, all laid with their grain parallel, and glued or otherwise fastened together. Glued lamination material is called –Glulam‖

2 The laminae, which may be thin veneer or boards are first seasoned in kilns. They are then cut to uniform width and length. Width or length insufficiencies are met by edge-gluing and end-joining. To develop joins of maximum strength the surface to be glued are cleanly machined to fit accurately. The laminae are arranged in proper order and fed into a glue spreader to spread glue properly.

3 The glued laminae are then placed on a Jig or form for assembling to the required shape and pressure applied by means of clamps fitted at regular intervals

Advantages and limitation of laminated wood

Wood-metal laminates : Laminates made of wood and thin metal has high cleavage strength and freedom from splitting.

The difficulty in wood metal joining has been got over by adhesive like Redux

glue which is a combination of thermosetting and thermoplastic glue.

Aircraft wings and fuselage panels bonded with Redux develop shear stress 25% higher than those with riveted or spot welded joints.

Furniture are made from veneer and aluminum panel(—Vendurall).It is resistant to heat, has appearance of wood and strength of metal, resistant to termite and insect attack, chemical attack. Offers new design.

Block board or core boards

It is made up of strips of wood each not more than 2.5 cm wide, laid separately or glued or otherwise joined together to form a slab,

The slab in turn is glued between two or more outer veneers with the direction of grain of the core strips running rt. angles to that of the adjacent veneers.

Block board construction aims at lightness of weight and economy in the use of wood. It helps in utilization of sawmill waste.

block boards (core boards) having fiber board, chip board, or hollow materials as cores are used extensively these days.

Block board with strips of wood arranged in honeycomb shape in the core are called hollow boards. They save raw material up to 60% and are half in weight than the solid block board of same size. Such hollow boards are extensively used in partition and doors for their low weight, better stability and good acoustic and heat insulation property.

Other Core boards:

Batten board : core made up of strips of wood not more than 7.5 cm width. Block

board : core made up of strips of wood not more than 2.5 cm width.

Lamin board or lamin wood : core made up of strips of wood not more than 7 mm width

.

Fiberboards

Fiberboards are made from fibers of wood or other ligno-cellulosic materials (jute sticks, mustard stalks, tapioca stem, coconut husk, reeds, lops and tops in forest felling, and other wood wastes).

The wood or other vegetable material is first defibrated and reduced to pulp. The pulp thus obtained are then converted into a mat from a water slurry on the screen of a paper machine.

The wet mat is then compressed and dried into a compact sheet under control temp and pressure.

Modern industries uses semi-dry process where fibers are carried in air suspension instead of water suspension In wet process lignin's are partially hydrolyzed which then serves as natural binding agent.

With controlled moisture, temp, and pressure a natural ligneous bond may be produced in dry process also but bonding agents like glues, and synthetic resin like adhesive needs to be added to serve as a binder.

Synthetic resins like phenol-formaldehyde are added to improve properties like mechanical strength and resistance to moisture at the felting stage.

Fiber boards are also used as core material for core boards.

FBs are manufactured in densities ranging from 32 to 1440 kg per cu m.

Lower density boards are used in insulation while higher density boards are used as structural material.

FBs are primarily classified according to density.

British common wealth terminology distinguishes three types…. Hardboard (density greater than 481 kg per cu m), Wallboard (density between 400 and 481 kg per cu m), and soft board (density less than 400 kg per cu m)

In India fiber boards are classified as .Insulation board (445 kg per cu m), Wallboard (481 kg/CM), Medium hardboard or tempered board (481 to 890 kg/CM), Standard hardboard(more than 890 kg/CM), and Super hardboard or tempered hardboard (1200 kg/CM to 1450kg/cm).

PARTICLE BOARDS

It is constituted from fragments of wood and/or other ligno-cellulosic materials (chips, shavings, flakes, splinters, sawdust, etc.) bonded with organic binders with the help of one or more agents like heat, pressure, humidity, catalyst, etc**.**

Such boards are named according to the purpose of their use like..Building board, Insulating board, wallboard etc.

Particle boards are also used as core material in core boards.

Types of particle board:

According to type particle boards can be divided into

1.Chipboard : a particle board made from chips. It is made in different thickness

and are surfaced with paper, veneers, plastic materials etc

2 Flake board: A particleboard in which wood is in the form of flakes giving surface a characteristic look.

3. Shaving board : A particle board in which wood savings are the main constituent.

Classification of particle boards

Depending on their density, particle boards have been classified as..

a. Low density board : sp gr 0.2 to0.4
b. Medium density board : sp gr 0.4 to0.8
c. High density board : sp gr 0.8 to1.2

Manufacture of particle board

1 Raw material (flakes, splinters, shavings and pieces of waste wood or lops and tops of trees etc) is chipped in a chipping machine.

2 Chips thus obtained is screened to get particles of more or less uniform size.
3 Oversized particles are reprocessed and used. Very small particles require large amount of adhesive so are discarded.

4 Screened particles are then passed through drier to remove excess ofmoisture.
5 Dried particles are then mixed thoroughly in a mechanical mixture with aresin adhesive.
6 Other additives like wax and preservatives like Ascu, Celcure are also added in the mixture if needed.

7. The mix is then flat-pressed in a hot press at suitable temp and pressure. Or by continuous extrusion through two rigidly mounted heated platens.
8. Thickness of the board is controlled by regulating the space between the platens.

9. Consolidation to the desired density is attained by controlling the pressure,heat and quantity of the mix.

Difference between particle board and fiberboard

a. Basic particles in fiber board is pulp made up of individual fibers or small clumps of fibers while in particle board basic particle is chips, flake, splinters which exhibit characters of original wood.
b. Fiberboards depend for their cohesiveness upon the mechanical felting of the fibers brought about by the formation of a natural ligneous bond on the application of heat and pressure, Particle boards on the other hand, depend almost entirely on the adhesive additives for their cohesiveness.

6.Bamboo boards

c. Strips of bamboo are woven into mats. Then they are dried to a moisture content of 8 to 12percents.
d. They are then dipped or brush-painted with phenol-formaldehyde solution.
e. They are then conditioned and pressed at 140 degree centigrade at a suitable pressure.
f. Board may be of single mat or of several mats pressed together.
g. Satisfactory boards are made with a resin content of 15% and pressureof28 kg per Sqcm.

h. Bamboo boards are excellent in tensile and bending strength (modulus of rupture 630 kg/sq cm and tensile strength 644 kg/sq cm), and also goodin water resistance.
i. Can be made fire-resistant by using sand as a filler.
j. Irregularities in the surface can be minimized by using saw dust as filler.
k. Suitable for furniture, hollow types are good for insulation, partition walls, flush doors, decking etc.

7 SAWDUSTBOARDS

8 **OTHER BOARDS** (bark, grass, straw..boards)

CHAPTER 8
WOOD PRESERVATION

IMPORTANCE

Preservatives increase the life of wood 4 to 5 times in open uses and 7 to 10 times in interior uses.

Preservatives increase fire resistivity in wood (2 to 3 times than wood with no treatments).

Preservatives increase the durability of wood (60 to 70 years more than ordinary woods).

Scope of preservation in India:

- In Railway sleepers.
- In Transmission poles.
- In other constructional purposes.
- In packing cases.

Characteristic of wood preservatives

1. High toxicity (even in low concentration)
2. High permanency under all service condition (resistance to bleaching, rapid evaporation, chemical reaction, polymerization, oxidation, reduction etc.)
3. High penetrability (ability to get inside easily)
4. High stability during treatment (resistance to decomposition at temperature used during treatment)
5. Be cheap and easily available.
6. Must not increase inflammability.
7. Must not impair health of labors.
8. Allow paint and varnish easily.
9. Must not corrode the metals used during treatment.

Types of preservatives:

1. Oil type
(tar-oils)

2. Water soluble leachable type. (Ascu, Celcure, Bolide salt)
3. Water soluble fixed type.
4. Organic solvent type.

(Copper and zinc salt of organic acids like naphthenic acid, steric acid etc

and chlorinated phenols and benzenes like pentachlorophenol, benzene hexachloride, DDT, dieldrin).

Methods of preservative application:

1. Surface application
(spraying ,brushing)

2. Dipping, steeping and diffusion
(in vat , in kiln or in suitable vessels)

3. Hot and cold
process (open tank
treatment)

4. Boucheric process

5. Pressure process

a. Full-cell process (Betha lprocess)
b. Empty-cell process (Lowry process)
c. Rueping process

6. Special treatment for green timbers

a. Boulton process
b. Steaming cum vacuum process)

Chapter 9
PULP AND PAPER TECHNOLOGY

9.1 Raw materials

9.2 Pulping process
- **a. Mechanical**
- **b. Chemical**
- **c. Semi chemical**

9.2 Paper manufacturing
9.3 Lokta pulping and paper making

ORIGIN

- T‘ Sai Lun (105A.D.)---China
- Till 15th century all paper was made by hand
- Louis Robert 1799---first paper making machine was made
- Henry and Sealy Fourdriner in 1803 erected improved version.
- Keller and Voelter in 1844 developed the process for the manufacture of mechanical wood pulp
- Watt and Burgess in 1854 patented a process for producing pulp from wood by treatment with caustic soda (Chemical wood pulp)
- Routledge in 1860 used alkali for cooking grasses to produce pulp
- Tilighman (USA) in 1866 produced pulp using bisulphites

1. RAWMATERIALS

- Plants are the only source of fibrous raw materials for papermaking.- Thousands of species from common grasses to giant trees.
- But economically suitable as a raw material for paper-making is relatively limited
- Plant is composed of cell. They in turn are composed of cellulose. They are fibrous substance, insoluble in simple solvents, and is resistant to dilute alkali and dilute acids. Closely associated with cellulose are non-fibrous hemi cellulose , lignins and other constituents like tanins, resins, waxes, and other mineral substances.

  On the basis of the location in the plants, raw materials for paper making may be classified as follows

  1. Seed hairs ----cotton
  2. Bast fibers ---- Hemp, Jute, Lokta
  3. Grasses ---- Straw, Sabai,
  4. Wood fibers---- Coniferous and broad leaved woods
  5. Leaf fibers---- Manila, etc

Cotton is the seed hair fiber and is purest form of natural cellulose. Almost all of the cotton produced in the world is used for textile production. Pure cotton papers are highly expensive. Only rejects and discards of textile are available for paper

making.
Cotton papers are strong, durable, permanent and have good finish. It can be used for the manufacture of variety of paper products like blotting paper, currency notes, permanent edition on News paper, long lasting legal documents and letter pads, religious books, etc. But as the cotton paper is very expensive , it is used only there where price is no problem.

Linen (Linum usitatissimum), **Hemp** (Cannabis sativa), **Jute** (Corchorus capsularis and corchorus olitorlus) are bast fibers. Paper made from Linen and Hemp bast fibers are strong, permanent and durable. Fibers are in general 2.5 mm in length and 0.02 mm in diameter. Jute fiber is used to make strong wrapping papers.

Straw fibers are obtained from stems of various cereal plants as wheat, oat, barley, rice etc. Fibers are 1.5 mm long and .015 mm in diameter. They are cooked with caustic soda and then bleached. They are then mixed with longer fibers like wood pulp or rags to use it in making good quality writing and printing papers.
Although sabai grass (Eulaliopsis binata) fibers do not require mixing with longer fibers but sometime straw fiber is mixed when there is shortage of sabai grass or quality increase is required.

Wood fibers are most widely used for paper making (97% of paper produced inthe world). Both coniferous (83%) and broadleaved (14%) wood pulp are used to make paper.
Dimensions and chemical composition of wood fibers

Fiber length	3 to 3.5mm
Fiber diameter	30 to 40 microns
Mineral matter	1 to 2 %
Extractives	4 to 12 %
Cellulose	40 to 45 %
Hemicellulose	15 to 20%
Lignins	26 to 30%

Following factors are taken into considered during selection of raw material for paper making:

1. Economic Aspect

1. Supply in Plentiful.
2. Extraction, collection, and transportation cheap
3. Regularity in quality and quantity
4. The cost of processing and purpose of making
5. Supplies of raw material should be easily replaceable.

2. Technical Aspect

1. Ease with which non fibrous materials can be removed.

2. Quality of the pulp produced.
3. Quantity of the pulp produced.
4. Consumption of chemicals, power, and steams for pulp production.

* In India the main raw material used for paper making Bamboo, Sabai grass, Bagasse, Jute sticks, Mixed grasses, Wastepaper, and woods of coniferous and broad leaved trees are used.

9.1 Process of paper-making

Process of paper-making consists of FIVE main steps

1. Pulping
2. Pulp cleaning
3. Pulp bleaching
4. Stock preparation
5. Sheet formation

Pulping

It is the process of isolation of cellulosic fibers from raw materials. There are three ways in practice to isolate the cellulosic materials .

1. **Mechanical process**
2. **Chemical process**
   a. **Alkaline process**
   b. **Acidic process**
3. **Semi-chemical process**

1. Mechanical Process

In this process no chemical is used to disintegrate the wood into fibrous state.

Process involves the wet grinding of wood into a fibrous mass by means of a revolving grinding stone.

Logs of debarked wood are held against the revolving stone and, as the stone grinds the wood , a stream of water is spread on the stone to carry the pulp away.

The logs are held against the revolving stone in transverse fashion, with the length of the log parallel to the axis of the grinding stone, to obtain long fibers.

Forces of friction tear fibers from the logs and the fibers are carried in the grooves of the grinding stone to the grinding pit.

Pulp flowing out of the pit is passed through metal screen having perforations of about 6 mm diameter to remove the coarse materials. The rejects are re processed in disc refiners and mixed with the pulp and passed through the screen again.

It is then passed through a complex screening and cleaning system to screen out shaves, splinters, sands and other dirt. The screening of the pulp is done at a low consistency.

Pulp is thickened afterward by removing excess water in thickeners or deckers. Water thus removed in the process of thickening is re-used in screening.

Eucalyptus, poplar, light colored conifers are preferred for making mechanical pulps. Pulp yield obtain by mechanical pulping is 90 to 95 % and power required is 1100 to 2000 KWH per ton of pulp production.

Mechanical pulp are used in manufacture of newsprint paper. Cost of production is very low compared to the chemical pulp production. But the paper is of low quality in color, strength , and durability.

2. Chemical process

It is the process in which the lignin, the binding material of plant fibrous raw materials, is removed by digesting the raw material, cut to the suitable size, In the presence of chemicals.

If the cooking chemicals used is alkaline‘ in nature, the process is called alkaline process‘

If cooking chemicals used is acidic in nature, the process is called acidic process

A. ALKALINE PROCESS

- The two principle alkaline process used for pulping are
- (a)_soda process and (b) _ sulphate process‘
- In both the process sodium hydroxide (NaOH) is used as cooking chemical.
- In _soda process‘ only sodium hydroxide (NaOH) is used in cooking .
-
- While in- sulphate process‘ sodium sulphide(Na2S.9H2O) is also used in addition to sodium hydroxide.

- Use of_ soda process‘ is restricted to grasses and agriculture residues. For other raw materials _sulphate process‘ is used.

Sulphate process

- Pulping is carried out in welded steel digesters usually without lining. Digestion is carried out under heat and pressure. Condition of cooking is precisely

controlled according to the types of raw material used and quality of pulp required.

- When cooking is complete, the cooked mass is blown into blow tank by pressure. It helps to separate the fibers in the very soft chips. Pulp is then washed in washers repeatedly till the fibers become free of black liquor. The black liquor is send to the soda recovery unit to recover the chemicals and the pulp is processed further.

Advantage of sulphate process

- Maximum flexibility with regard to species
- Shorter cooking period
- Pulp is bleached to quite high brightness
- High pulp strength
- Absence of pitch problems
- Production of valuable by-products in the form of turpentine and tall oil
- Efficient chemical and heat recovery
- Relatively low stream pollution

B. Acidic process

- In this process Fibrous raw material are digested with ‗cooking liquor'.

- Cooking liquor' is composed of calcium bisulphate $Ca(HSO4)2$ and excessively large amount of sulphur dioxide ($SO2$). Liquor is very acidic. The process is called ‗sulphite process'.

- Sometimes the digestion is carried out in liquor composing magnesium or ammonium bisulphate with a small excess of sulphor dioxide.

- Inner walls of the steel digesters inside which raw material are cooked is protected by an acid resistant brick-lining.

- The cooking liquor 'is prepared by burning sulphur or iron pyrites in air to form sulphur dioxide. $SO2$ thus formed is passed through absorption towers containing limestone ($CaCO3$) over which water flows. It dissolves in water forming sulphurus acid ($H2SO3$) which in turn dissolve lime stone forming calcium bisulphate $Ca(HSO3)2$.An excess of $SO2$ is kept in the cooking tower.

- Waste liquor from sulphite process is discharged in general into astream. Recovery of chemical is normally not done due to several reason as the deposition of calcium compounds.
- Very few mills use the waste liquor as a source of lignin, alcohol, vanilinetc.

5. Semi-chemical process

- Raw material chips are first subjected to a light chemical treatment and then is followed by a mechanical de fibrating.
- Chemical used to help the softening of chips and removal of lignins are neutral sulphite, high yield sulphate, high yield sulphite and cold soda.
- The use of high yield sulphate is well established for conifers and now is used for hard woods also.
- Bleached neutral sulphite semi-chemical pulps of hardwoods have high strength properties and so is used for printing, writing and other fine paper and paper-boards.
- Unbleached neutral sulphite semi-chemical pulps of hardwoods are used in the production of corrugating medium.

PULP CLEANING

- The digested pulp contains some impurities like knots, shives, dirt, grits etc., which needs to be removed before further treatment. It is done by pure mechanical means.

- Pulp of low consistency is screened step by step over flat screen and centrifugal screens to remove different types of physical impurities. First knots, second shives, then dirt and grits.

PULP BLEACHING

- It is a process in which the remaining impurities that imparts a poor color to the pulps are either removed or discolored.
- It is done systematically step by step to a desired stable brightness.
- Bleaching is done by oxidising or reducing chemical agents. Most common are chlorine and its compounds.
- Pulp can be bleached in a single stage or in several stages.
- In a single stage bleaching , bleaching powder ($CaOCl_2$) is widely used, while in multi stage bleaching chlorine gas (Cl_2), and chlorine dioxide (Cl_2) are used.
- In recent days , peroxide and hyper sulphides are normally used in semi-chemical and ground wood pulps for improving brightness.
-

STOCK PREPARATION

There are five steps in stock preparation.

<u>Beating</u> :

1. **Beating**
2. **Sizing**
3. **Loading**
4. **Coloring and**
5. **use of other additives**

Cellulose fibers must be subjected to mechanical treatment before it can be formed into sheet of paper. The term ‗beating' and ‗refining' are used for the mechanical treatment given to fibers in paper industry. Large amount of power is required to perform this operation.

Increased Beating increases bursting strength, tensile strength, folding insurance, smoothness, and rattle. But increased Beating reduces tearing strength, bulk, porosity, opacity, and dimensional stability. So beating is adjusted to a suitable extent to produce particular type of paper. By adjusting beating process many types of paper can be produced. Beating is done in a Beater machine'

The principal effects of beating are mostly physical.
The important effects are:

- Fractures and partially removes the cell wall
- Decreases fiber length
- Increases fiber flexibility
- Helps in formation of fibrils
- Retards drainage
- Increases external surface of the fibers.

Sizing

- Paper less impervious to the penetration of ink is said ‗sized paper'
- Absorbent papers are called ‗water leaf papers'
- Rosin soap along with almunium sulphate (alum to paper makers) is added to size the paper.
- Rosin soap is made by saponifying rosin in alkiali.
- Wax emulsions are also used but care should be taken to avoid wax spoting paper

Loading:

- Addition of non-fibrous mineral to stock prior to sheet formation is known as ‗loading Materials used for loading is known as‗ fillers
- In old days addition of mineral matters to pulp suspension was taken as adulteration.
- Common fillers are china clay, talc powder, and titanium oxide. Other fillers like calcium carbonate, barium sulphate etc. are also used.
- Fillers are added in the‗ beater 'during beating after making a slurry of pulp in water.
- Fillers improves ink absorption, gives better surface finish, gives more softness, brightness, and dimensional stability but reduces the overall strength of the paper.

Coloring:

- Almost all paper produced today are colored to some extent
- Coloring is done in beater.
- Both insoluble pigments and water soluble dyes are added.
- To impart perfect color selection of correct dye in correct amount is required. Brightness of paper is also the most important factor.

Use of other additives:

- Other additives are used to give special characteristic to a paper
- Other additives may be starches, vegetable gums, synthetic hydrophilic materials, and resin emulsions.
- They are added in ‗beater' and are called as ‗beater additives'.
- Some time they are added at the ‗fan-pump 'or ‗head box' of the paper machine. They are then called ‗wet end additives'
- .

SHEET FORMATION

- After pulp has been treated for stock preparation, it is carried to the paper machine for conversion into paper.
- There are two principal types of machine (1) Four drinier machine and (2) Cylinder mould machine.
- The beaten stock is passed through a cleaning equipments after reducing its consistency (normally around 0.5 to 1.0percent).
- Cleaned pulp of such a low consistency is fed to a flow box and slice for the maintenance of an even flow, free from eddies and cross currents across the width of the machine.

Fourdrineir machine

In this machine a long, endless wire on which pulp travels is used. During travel, water is drained leaving a wet web of paper. Wire is given a shaking motion towards the flow-box side, to improve paper formation. The wire is supported by a number of small diameter rolls known as ‗table rolls'. In addition to supporting the wire, these rolls helps in removing water from wet web. Wire is moved over several suction boxes for further removal of water. Water marks are impressed on the paper at this stage by means of a skeleton roll, known as ‗dandy roll' which is inserted between the suction boxes. The last roll which drives the wire is known as ‗Couchroll'.Thiscouchrollalsofurtherremovesthewaterfromthewetweband makes it sufficiently strong so that it can be passed over to the press section.

Cylinder Mould machine

In this machine, the stock is picked up on a wire covered cylinder roll which rotates in a vat containing stock of low consistency. The wet web formed at the cylinder is passed to a felt which carries it to the press section. Several vats are used to make thicker boards, wet mat of one mould laminates with the wet mat of next mould.

Wet web from in either machine is fed to the press section. In press section wet web is carried on a woolen felts and is pressed by several presses. It is then the pressed sheet is passed to the drying section. In the drying section, the wet sheet carried on an endless cotton and asbestos felts are passed over several hollow steam heated cast-iron rolls. Several driers are used to remove all the water and to make sheet perfectly dry.

To give paper sheet required degree of smoothness, it is passed through polished hot rollers. Some papers are made with high polish in one side. To make this type of paper wet web when it is still moist is pressed over a single, highly polished, steam heated, large cylinder known as _M.G. cylinder of cast-iron rolls known as _calenders. After calendering it‘ or _Yankee cylinder‘. It is then rolled over spools.

Flow chart wood to paper

Primary process

Wood---debarking---chipping---screening----pulping---
---pulp cleaning-----bleaching----washing--screening--beating---sizing—loading—coloring—pressing --drying--cutting—sorting—spool making--storing.

Secondary process

Pulp washing—black liquor storage—soda recovery—white liquor----discharging.

UNIT -9
WOOD ENERGY

9.1 Wood as fuel energy.
9.2 Importance of fuel wood.
9.3 Methods of efficient use of fuel wood energy, improved cook stoves, charcoal& briquettes.

9.1 Wood as fuel energy.

Fuel wood

- It is a direct source of energy.
- Requires little or no treatment.

Source of fuel wood

- Lopping of branches of standing trees or shrubs
- Felling of dry, diseased and dying trees or shrubs and their conversion into billets.
- Removal of lops and tops of the trees felled commercially and use the mass source of fuel.
- Cutting trees planted for fuel wood purpose.
- Waste of sawmills and other wood based industries.

9.1 Importance of fuel wood

Importance over other energy source :

- It is Easily available.
- It is a renewable resource.
- Easy to harvest, no special technique or tools are required.
- Completely dry fuel wood contains up to 90% combustible material.
- Flame produced during burning can heat a large surface area.
- It can be obtained more or less free of cost so is popular in poor mass.

Combustion:

Carbon and hydrogen present in the wood combine with the oxygen of the air to release carbon dioxide and water. The inorganic elements present in the wood remains in the form of ash.

Combustion stages.

1st stage—moisture present gets evaporated—a part of the heat applied for

burning is used in it. So dry woods are more fuel efficient.

2nd stage---vaporization of the volatile substance—this produce flame in the fire—thick smoke is generated if combustion is not proper—in that case potential of fuel is not fully used– Resins present in wood also give smoke.

3rd stage---In this stage burning of cell wall takes place which are made up of cellulose. It burns glows without a flame. More heat is produced during burning of denser woods.

Combustibility :

It is the readiness with which the wood catches fire, and once it is on fire, the capacity to burn till only ash is left behind.

Calorific value :

It is the heating power of wood or quantum of heat emitted by a unit weight of wood during the process of combustion.

Factors affecting combustibility and calorific value:

- Quantity of moisture present. ----
- Internal structure
- Soundness- ----
- Extraneous substances
- Size
- Hardwood/softwood

Good and bad fuels : It is judged by

- Combustibility and calorific value.
- The quantity of smoke generated during burning.
- The rapidity of burning, heating and the quietness with which the wood burns.
- The odor or smell produced during burning.
- Ease and completeness in burning.

Good fuel woods :

Adina cardifolia, Albezia sp, Castonopsis sp, Dalbergia sisso, Gmelina arborea, Juglan regia, Lagerstroemia sp, Mesua ferra, Rhododendron sp, Schima wallichii, Shorea robusta, Quercus sp, Syzyzium cuminii, Tectona grandis, Terminalia sp.

Bad fuel woods :

Ficus sp, Pinus sp, Picea smythiana, Garuga pinnata, Madhuca sp, Cedrus deodara, Eucalyptus sp, Populas sp.

WOOD CHARCOAL

Charcoal :

Charcoal is a carbonized form of wood derived from its destructive distillation in the presence of limited but regulated quantities of air.

Selection of raw material :

- Young wood with high content of sapwood is less suitable.
- Woods with large annual rings and wide vessels gives less qualitative charcoal than from wood with narrow rings and small vessels.
- Old, rotten and porous wood yields fissured, weak and friable charcoal.
- Wood with bark is avoided.
- Wood moisture content must not be above 30 to 40%.
- Any species of wood with dense structure and narrow annual rings will produce high quality charcoal

Process of Carbonization of wood :

The stages involved in carbonization are:

- At about 150 degree C moisture present in the wood turns into vapor.
- Further rise in temperature decomposes the cellulosic material.
- Volatile substances in the wood like pyroligneous acids, methyl alcohol, acetone, carbon monoxides and carbon dioxide escape out.
- The residue left behind is charcoal.

Role of temperature in Carbonization of wood :

- Charcoal making is a process of conversion of wood into a more readily useable form.
- High temperature and rapid combustion gives low yield. Low temperature and slow combustion gives high yield.
- With increase in temperature volatile substance goes on escaping and the residual charcoal becomes richer in carbon. For example in150 degree it is around 47.5% where as at 1750 degree C it is96.2%.

Role of temperature in Carbonization of wood …

- Ideal temperature is about 350 degree C when charcoal contains 77% of carbon.
- But once wood is heated to 350 degree C reaction becomes exothermic and reaches 500 to 600 degree C. Charcoal formed at this range of temperature has 81% carbon content.
- Charcoal formed at 350 degree C with 77% carbon are richer in volatiles and easier to ignite than that formed towards 600 degree C even if carbon content is 81%.

CHARCOAL BRIQUETTES

Briquettes and its importance :

- Charcoal briquettes are also called bio-briquettes.
- They are made up of charcoal dust mixed with appropriate amount of clay.
- It is a clean energy source than wood or charcoal as they burn without smoke, smell, and noise.
- Easy to transport and easy to light.
- Can be made in different shapes and sizes. So can be used in different types of kilns for various purpose of heating.
- Best utilization of waste woods, saw dusts, lops and tops agri residues, unwanted herbs and shrubs etc… to produce energy.

Briquette making techniques:

- First charcoal made from wood or any vegetative material is crushed to powder.
- The powder is then mixed with clay (or an organic soil) in fixed proportion.
- The mixture is then put in the mold of required shape and size and briquettes are casted.
- Wet briquettes are then dried in sun or in heat to make it dry.
- Briquettes are then packed in packing cases carefully so that they do not get crushed during transportation.

IMPROVED COOK STOVES

Traditional stoves

- They are not fuel efficient.
- Produce lot of smoke which is hazardous to cook‘s health.
- Safe smoke escape provision is absent in traditional stoves.
- Heat utilization is not good.
- Cooking in traditional stoves is one of the reason of asthma and other lungs disease among womenfolk who are responsible to cook food in almost all families in rural area.

Improved stoves :

- They are fuel efficient.
- There is safe smoke escape provision in it.
- Heat utilization is maximum.
- Can save time in cooking or heating.
- Less or no chance of degradation of cook‘s health.

CHAPTER 10
NON-TIMBER FOREST PRODUCES

General

All biological resources (other than timber) that may be extracted from natural ecosystems , managed plantations, etc. and be utilized within the household, be marketed , or have social cultural or religious significance (Wickens, 1991).

NTFP includes Organisms such as bacteria, fungi, mosses, lichens, ferns, higher plants, wildlife and their products (Peters, 1994).

Non Wood Forest Produces (NWFP):

The term NWFP excludes all woody raw materials. Consequently, timber, chips, charcoal and fuel wood, as well as small woods such as tools, household equipment and carvings, are excluded.

Non Timber Forest Produces (NTFP):

Non-timber forest produces (NTFPs), in contrast, generally include fuel wood and small woods; this is the main difference between NWFPs and NTFPs.

The term "produce" corresponds to goods that are tangible and physical objects of biological origin such as plants, animals and their products.

Forest services (e.g. ecotourism, grazing, bio-prospecting) and forest benefits (e.g. soil conservation, soil fertility, watershed protection) are excluded.

Services and benefits are difficult to assess and quantify and so have been excluded from most publications dealing with NTFPs. A clear definition of forest services and benefits is still lacking.

NON-TIMBER FOREST PRODUCES

1. Medicinal and Aromatic plants-
2. Gums and Resins-
3. Bamboo and cane products-
4. Lac, silk and beekeeping-
5. Tans and dyes-
6. Fiber and flosses.
7. Oilseeds.-
8. Distillation and extraction products, including, grass oils.
9. Animal, minerals and miscellaneous products
10. Forest services and benefits.
11. Spices, edible products and poisons.

1. Medicinal and Aromatic plants (MAP)

- Plants are the most important source of medicines, drugs, insecticides, pesticides and even poisons.

- These products may be obtained from many plant species growing in forests, pastures, marginal lands and even on cultivated lands.

- They serve as an important raw material for the commercial production of many medicines and drugs.

Overview of MAPs

- Our country is extremely rich in medicinal and aromatic plants.
- Out of 5856 flowering plants recorded in Nepal, 690 sps are considered to have medicinal properties (Malla and Shakya).This number includes 510 species found in wild; 120 species native in cultivation , and remaining 60 species are exotic.

- MAPS is not a well defined term in literature. Any plant used in any type of medicinal system such as ayurvedic , homeopathic , or amchi (traditional Tibetan ethnic healing system) etc. are defined as medicinal plants.

- ***Aromatic plants is one having aroma in any of its part***
- 30% MAPs occur in the western part of the country (manandher,1998).
- 50% of the MAPs are used as ethno medicine in Nepali Himalayas (kuwnar et al 2008)

- Jadibuti is also more frequently used in the context of India & Nepal.

- Majority of people living in or around forests of developing countries depend on MAPs as supplementary sources of cash income for fulfilling their subsistence requirement.
- MAPS can provide new opportunities in national income as well as in the income of common villagers.
- About 100 MAPS are traded annually from Nepal (Amatya2000).
- Among them 23 MAPs are being traded in high value.
- Estimated market value of herbal medicine alone (a large proportion of which is collected from the wild) is about 14 billion US dollar (secretariat of CBS, 2001).
- The revenue generated by NTNFP represents only about 5% of the total revenue of the forest department.
- Collector, porter, village trader, independent collector are beneficiaries from trade of MAPs along with city level wholesale collector and national level wholesale trader.
- The information base on high value MAPs is extremely poor as most of the trade remains illegal.
- The world market for herbal medicines in 1999 was calculated to be worth US 19.4 billion.(laird &pierce,2002)
- The market for ayurvedic medicine is estimated to be expanding at20% annually in India(subrat,2002)
- The reported annual imported of medicinal plants material into all countries during the 1990s amounted to an average of 400,000tons,valued at US$ 1.2 billion, showing a 100%rise between 1991 and1997(lange,2000).
- Between 50-100% of house hold in the northern parts of central Nepal and about 25-50% in the middle part of the same region are involved in collecting medicinal plants for sale. The collected materials are traded to wholesale market in Delhi (olsen,1997).
- These data shows the importance of commercialization of MAPs
- The development of MAPs based pharmaceutical industries is to be established to uplift the economic status of the country.
- Large-scale commercial plantation of potential MAPs in private land, extension program, simplification of taxation modality ,providing easy access to the laboratories, assistance in the market must be enhanced by the state to generate the active participation in cultivation and trade of MAPs.

Collection and extraction of MAPs

- Collection approval of MAPs are offered each year by the DFO just before the collection season
- To collect MAPs to the extent of 5 to 50 tons for barks and 10 to 100 tons for oil extracts per sps require IEE.
- To harvest beyond this limit requires EIA.
- Collection of MAPs may be plant as a whole or in parts like leaves, roots,

bark, fruits, flowers.

- Leaves are harvested during November to February in a sustainable manner.

MAPs Collection Tips

1. If stem has to be collected:
   Collect from plants thicker than thumb.
2. If Leaf has to be collected:
   Gather fallen leaves only and do not axe down the tree as a whole or its branches as far as possible and absolutely necessary.
3. If Flowers and fruits have to be collected:
   Do not cut branches. Leave few good fruits and or flowers in each branches of the plant.
4. If Root has to be collected:
   Uproot the plant only after seeding. For tuberous plants uproot the plant fully so that under ground portion is not wasted. Leave a few bulbs or a portion of rhizome for sprouting.
5. Right time and season along with appropriate harvesting techniques are needed for efficient collection and extraction of MAPs.
6. Collection of plant before flowering and seed dispersal hampers regeneration from seed while uprooting of whole plants increase soil erosion (as in case of jatamasi) leading to landslide and ultimate destruction of the MAPs habitat.

   Domestication/cultivation, ex situ conservation, wild harvesting and in situ conservation, traditional and ethical practice are some methodology in collection and extraction of MAPs
7. Proper care and precaution must be taken during collection and extraction of MAPs.

Parts used for NTFPs

- The entire plants or parts like leaves, roots, stems , barks, fruits, flowers canbe used for medicinal purpose.
- Rhizomes leaves, seeds are used for extracting essential oil.
- The quality or medicinal value of the collected parts depends also upon storage place and container used to store.

Processing of NTFPs

- A few MAPs are of high economic value
- Scientific management of such species along with quality processing and refining gives more economic out put
- Traditional marketing system needs to be displaced by new technical marketing system.
- In the context of Nepal for most of the MAPs processing technology practiced

are drying, grading, packaging, distillation of essential oils, debarking, paper making, rope making, stitching etc. only

- A few NTFPs like resins, katha, and some essential oil are processed further by processing industr

Some Important medicinal plants

Adhatoda vasica(asuro)

Tall densely branched evergreen shrub with large lense shaped leaves, flowers are white and in spikes, fruit four seeded and capsular. Found in plains and in parts of lower and outer himalayan region, generally in wastelands and fields. The drug vasica is made from fresh or dried leaves of the plant. Drug is used as an expectorant. Softens thick sputum.

Aegle marmelos *
Atropa belladonna
Azaderachta indica *
Berberis aristata
Cinnamonum zeylanicum
Cinnamonum tamala *
Dioscorea deltoidea *
Emblica officinalis
Picorhiza kurroa *
Madhuca indica
Nardostachys jatamasi *
Ocimum sanctum
Piper longum
Piper nigrum
Pterocarpus marsupium
Rauwolfia serpentina *
Swertia chirayita *
Terminalia chebula *
Terminalia bellerica

MAP description technique in field

- Scientific name, local name.
- Tree, shrub or herb.
- Deciduous or evergreen, perennial or seasonal.
- Tree‘s and leaf‘s size and shape.
- Flowering and fruiting season, their color and look.
- Parts used and their medicinal value.

1. Gums andResin

Resin tapping :

- Chir pine trees found in the hills of Himalayan are tapped for resin for the manufacture of rosin and turpentine.
- Resin is secreted from two types of resin canals – large longitudinal ducts in the wood and similar ducts in the rays occurring at right angles to them.
- Beside chir pine , the other pines which yield resin in significant quantity are, khasi pine, blue pine, and tropical pines. However tapping them is not commercially viable.

Different methods adopted for resin taping.

1. Box method

This is the oldest method. A cavity is cut at the base of the tree. The resin that exudes from the cavity is collected in a box. This method is wasteful and the trees began to die after a few years.

2. Cup and lip method

In this method a blaze is made on the stem of the tree after scrapping the outer bark. At the lower end of the blaze a metal lip is driven by nail to guide the resin flow that get exuded from the blazed wound. The blaze has a width of about 15 cm and length of about 25 cm. In a tree of large girth a number of blazes may be made simultaneously. The blaze is freshened from time to time. About 4 to 5 freshening may be required per month. Acid paste is also applied to induce the flow of resin. Resin is collected in a container placed on the ground exactly below the lip.

3. Rill method

This is recently developed method and is adopted in large scale these days. A part of the outer bark is removed and a series of rill like channels excavated in the stem. These rills are not very deep and hence the boles are not weakened as in cup and lip method. Method is the most cost effective also.

Factors affecting resin yield

a. Genetic characters of the tree being tapped.
b. Size and growth vigor of the tree.
c. Anatomy and structure.
d. Temperature and other climatic conditions.
e. Elevation aspect and slope.
f. Method of tapping and timing of freshening.

Processing of resin

- Resin is processed for obtaining rosin and turpentine. Crude resin contains impurities like water, pieces of barks and needles, other dirts, and even the remains of the insects.
- In the first step large sized impurities are removed by hand. It is then emptied into large melters or vats that has arrangement of stem heating, a helical mixer and v-shaped bottom.
- A small quantity of impure turpentine is added to the crude resin placed in the melter and steam heating is started. Helical mixer mixes the resin as it is heated. Then it is allowed to settle down. The heavy impurities go down at the bottom , while the lighter ones float at the top and may be removed by hand or some tools.
- The resin is then led to a sludge tank keeping behind the heavy impurities in the melter. Clean Resin is then pumped into a still vat with a steam jacket for distillation. The lighter oils are recovered first then the heavier ones. After recovery of all the turpentine rosin is left behind. It is drawn off and packed in a special wooden casks. The turpentine oil is further subjected to distillation to obtain pure turpentine oil.

Properties and uses of turpentine oil

- Turpentine oil is colorless and viscous liquid with characteristic odor and unpleasant taste.
- Its sp. gr. ranges from 0.85 to 0.88 while b.p. is around 155 degree c.
- On exposure to air turpentine oil absorbs oxygen of the air giving off ozone and becomes dry.
- It is used in the manufacture of paints, varnishes, shoe and other polishes.
- Used in the manufacture of chemicals, drugs and pharmaceuticals.
- Used in dissolving fats, resins etc.
- Used in manufacture of synthetic rubber, waxes, camphor, insecticides and germicides.
- It is colorless, red, brown or blue black. Sp gr about 1.08 and b.p. 100 to 140 degree c.
- It is used in the manufacture of soaps and for sizing of paper.
- Used in the manufacture of linoleum, sealing wax, oilcloth, special flooring compounds and coverings, lubricating compounds, ink, disinfectants, paints and varnishes.
- Used for soldering and as a dressing for machine belts and bows of violins and cellos.

2. Bamboos and canes ()

Bamboos :

- Bamboos are tall, perennial, arborescent grasses, belonging to Bombusaetribe under Graminae family. There are about 144 species in India. One or other

variety of Bamboos are found from terai plains to high mountains in Nepal.

- Bamboos are characterized by a woody stems, commonly called culms, which arise from the rhizome. Number of culms that arise from rhizome is variable. There is also great variation in the lengths of the culms. The growth of bamboos are very rapid. Most common bamboo in india is *Dendrocalamusstrictus*, the male bamboo of commerce. The next popular one is *Bambusaarundinacea*.
- Strength of culms, its straightness, lightness combined with hardness, their abundance, ease of propagation, make bamboos a useable commodity for a variety of purposes, ranging from house making to fountain pen making.
- Common uses of are in roofing, rafting, walling, flooring, matting, furniture, basket making, lathis, spears, bows and arrows, tent poles. Bamboo leaves are much valued as fodder and seeds are also eaten. Young shoots are pickled and eaten. It is an important raw material for paper and pulp.
- Bamboo flowers in gregarious. Once flowering takes place whole clump dies.

Canes

- Canes(or rattans of commerce)are the stem of climbing palms of the genus *calamu*s.
- The genus *calamus* consists of about 30 species of which around 15 are available in Nepal distributed from terai plains to high mountains.
- The stems of this climbing species are long (upto 100 meter), cylindrical, solid, and straw yellow in color. They are strong, tough and elastic. The outersurface is hard, smooth and shinning. The core is spongy. Cane reaches maturity in about 5years.
- They are used as substitute for ropes and cables, furniture frames, walking sticks, polo sticks, various sport goods, umbrella handles, basket making etc.
- Important species are *Calamus guruba, Calamus acanthospathus,Calamus tenuis,*etc.

3. Lac, silk and beekeeping

1. Lac :

Lac is a resinous substance secreted as a protective covering by the Lac insect *Laccifer lacca*, which lives as a parasite on many host plants.

The young red larvae of this insect live on the young succulent shoots of the host plants and draw nutrients from their sap. They secrete a thick resinous fluid to cover their bodies.

This secretion forms a hard and continuous encrustation on the twigs and branches of the host plant. This encrustation is collected from the host plants and processed to obtain Lac in commercial use.

Host trees :

Butea monosperma ---palas, dhak

Schleichera oleosa---kusum

Zizyphus maurtiana---ber

Properties and use

- It is soluble in alcohol and weak alkalis.
- Is elastic and adhesive in nature.
- Used widely in applying seals.
- Used to make musical records.
- Used for decorative and insulating varnishes.
- Used as coat for mewtal ware to prevent it from tarnishing
- Used as insulator
- Used in the manufacture of adhesives and cements, glazing paper, nail polishes, dental plates, jewelry fittings, bangles and grinding wheels
- Used in some types of confectionary also.

2. Silk

Silk is obtained from the cocoons of the silk worm.

i. Commonsilk

The common silk worm *Bombyx mori* produces silk in considerable quantity in various parts of Nepal. It feeds on the leaves of mulbery trees (*Morus alba, Morus indica* and *Morus australis*)

ii. Tussarsilk

Tussar silk worm *Antheraea paphia* feeds on many wild plants and produces famous tussar silk. The main plant species on the leaves of which tree they feed are--- *Anogeissus latifolia, Madhuca indica, Lagerstroemia parviflora and Termenalia tomentosa*. Silks are collected from two sources –from cocoons in the wild or from cocoons on plantations and orchards. In latter case eggs are collected from the plants in the forest and are placed in the plantations and orchards to develop to larvae. Two or three crops per year can be obtained.

iii. Muga silk

This worm is *Antheraea assamensis*. It thrives in species like *Cinnamomum obtusifolium, Litsaea spp, and Michelia oblonga*. It is found in wild and can be raised in farms. Raised in parts of Bengal and north east India.

iv. Erisilk

This worm is known as *Philosamia cynthia*. It is reared in parts of Assam, West Bengal, Bihar and Orissa for the production of silk.

3. Honey bees and wax

- Honey and wax has developed as a cottage industry in Nepal. It is obtained from the rock bee, *Apis dorsata* and the common Indian bee, *Apisindica*.
- Bees feed on nectar of plants occurring in the forests or in the agri-farms. They eat the nectar as their food and also store part of it as Honey after partial digestion.

- Bees are domesticated and raised for honey and wax. Honey may be collected two times a year. Combs are cut with a sharp knife and squeezed and sieved in fine muslin cloth to get honey. The residue remained is wax. Wax may be obtained from fruits of various forest trees also.

Uses of honey and wax

- It is eaten as delicacy or as a part of food preparations and confectionary.
- It has medicinal properties
- Wax is used for making polishes, varnishes, making water proof coatings to leather goods. It is also used for making comb foundation for artificial hives.

4. Tans and dyes

Tanin

It is a generic name given to a wide variety of chemical compounds secreted by plant tissues. Almost all plant tissues secret tanin although their quantity may vary from species to species.

Tanning

It is the process by which animal skins and hides are treated by tanins. Skins and hides are changed into leathers through this process.

Economic suitability

Suitability of tanin for economic exploitation depend upon a number of factors like—tanin concentration in plants, tanin and non-tanin ratio, acid and salt content, color, proneness to fermentation, quality of leather yield.

Tanin may be obtained from various part of the plant like from fruits, barks or leaves.

Fruit tans:
From fruits of trees like *Acacia sps, Emblica officinalis, Termenalia chebula etc.*
Barktans:
From barks of trees *like Acacia sps, Cassia auriculata, Cassia fistula,*etc.
Leaf tans:
From leaves of trees *like Anogeissus latifolia, Carissa spinarium* etc.

2. Dyes

Most plant tissues secret dyes as a part of their natural physiology. Dyes are simple compounds of hydrogen and oxygen with nitrogen present in few cases. Dyes are used in coloring fabrics. But as they are water soluble so fabrics are first immersed in solution containing a weak salt of iron, chromium, aluminum or tin so that thin layer of the oxide of these metal gets deposited on it. Fabrics are then immersed in dyes. Dyes then forms water insoluble compound with this thin layer of metal oxide.

Uses

For coloring cloth and leather, for coloring paint and varnishes, coloring ink and

paper, imparting color to medicines, drugs and food etc. Dyes are extracted from different parts of the trees like from barks, wood, leaves, fruits, flowers, roots etc.

Bark dyes:
It is extracted from barks of trees like *Acacia,*
Terminalia, Alnus , Artocarpus like sps.

Wood dyes:
It is extracted from woods of trees like *Acacia*
Pterocarpus santaline like sps .

Flower and fruit dyes:
It is extracted from fruits and flowers of *Sps like Butea monosperma, Mallotus philippensis,Toona ciliata*etc.

Leaf dyes:
It is extracted from leaves of species like *Lawsonia inermis* (henna)

Root dyes:
It is extracted from roots of species like *Rubia cordifolia* (manjit named red dye),
Morinda tinctoria etc.

6. Fiber and flosses

Fibers:

Classification based on origin and structure :

- Soft fibers from bast or stem like jute andhemp.
- Hard fibers from leaves like Agave, manila (Musa textilis) andargeli.
- Surface fibers from the surface of stems, leaves, or seeds like cotton, semal, kapok etc.

Classification based on use

- Textile fibers—cotton, jute, hemp and flax
- Brush fibers—hard fibers for making brushes and brooms
- Planting and weaving fibers –hard fibers with flat and pliable strands used for making hats, basket setc.
- Filling fibers—used for filling upholstery etc.
- Natural fabrics—tree basts extracted from the bark of some tree species.
- Paper making fibers– used for manufacture of pulp and paper

Flosses:

Flosses are obtained from the fruits of a number of trees and shrubs like *Bombax ceiba* (semul), *Calotropis gigantia*, *Ceiba pentandra* (kapok).

Coirs

The coir fibers are obtained from the thick fibrous husk of the fruit of *Cocus*

nucifera or coconut palm. It is used in making mats, brushes and brooms, ropes, and coir mattress etc.

7. Oilseeds

- Seeds of different plants yield different kinds of oils. However few of themonly can be used for commercialextraction.
- Seed oils are in general used alone or along with other raw materials in the manufacture of different kinds of products like scents, soaps, medicines,drugs andconfectionaries.
- Salseeds,seedsof*Shoresrubasta*arepopularinNepalfortheextractionof‗sal butter'. *Azadiracta indica* is famous for neem oil, *Madhuca butyracea* (Indian buttertree)isfor‗Phulwarabutter',*Madhucaindica*for‗mahuwabutter'etc.

8. Distillation products like grass oil, leaf oiletc.

Distillation of grasses like:

Citronella grass (Cymbopogon nardus), lemon grass (Cymbopogon flexosus), palmarosa grass (Cymbopogon martini).

Distillation of leaves like:

Eucalyptus leaves (Eucalyptus sps), dhasingare leaves (Gaultheria fragrantissima), mint leaves for mint oil (Mentha arvensis)

Distillation of wood like:

Sandlewood oil (Santalum album), pine wood oil (Pinus sps), agar oil (Aquilaria agallocha) etc produce aeromatic oils that are used in making various cosmetic, medicinal and sanitization products.

9. Animal, minerals and miscellaneousproducts.

- From Animals : Flesh, fats, horns, skins, bones, hairs, feathers, edible bird nests etc.

- From Minerals and misc products: Sand, boulder, stone, different kinds of clay and minerals, Fresh water etc.

- Forest services and benefits:
  Hunting, fishing, elephant riding, recreation in national parks and wildlife reserves, research, tourism, carbon fixing, good climate, water reserve, oxygen generator etc.

10. Spices, edible products and poisons.

Spices and edible products:

Dalchini, pipla, timur, amala, harro, barro, bel, koiralo, ban kurilo, niguro, tarul, bhyakur, gittha, chutro, mayel, kimbu, khanayo, timila, tama, tusa, mushrooms, okhar, katus, bayer, Cardamoms, katahal, mango, jamun, etc.

Poisons:

Abrus precatorius seed contains poison‗arbin'. Antiaris toxicaria bark exude white milk or resin from the bark which is used for tipping arrow for killing games. Barks of Albizia procera, Berberis aristata are used as fish poison. Milletia pachycarpa a large creeper contains‗rotenone' a well known insecticide used locally for poisoning birds and fishes