FOREST UTILIZATION-1

LECTURE NOTES

I. WOOD HARVESTING

1.1 BASIC LOGGING HAND TOOLS AND THEIR MAINTENANCE

The importance of forests for biological diversity, non-timber products, cultural values and environmental services is now recognized worldwide, and as a result forestry has become a more complex, more demanding discipline. One consequence of this increased complexity is that it is now more difficult to plan and carry out forest harvesting operations, as these must be designed and implemented in ways that accommodate and, if possible, enhance the multi resource character of the forest. To accomplish this, foresters, planners and logging operators require guidance on the practices that society is willing to accept and on the outcomes that are required in connection with forest harvesting operations.

A necessary condition for the sustainable management of forests is that utilization, and the activities associated with it, must not compromise the potential of forests to regenerate properly and to provide products and services that are essential for the well-being of both current and future generations. This condition can be met by following good harvesting practices.

1.1.1 Power chain saw and attachments.

Power chain saw is a portable tool that cuts wood with an endless chain that is driven by a motor and made up of many connected sharp metal teeth.

Figure of a petrol driven power chain saw duly labelled various parts is given below

Chain

Guide BarScabbard

Sharpening KitBar & Chain Oil

Safty gears

Gloves

Chain saw chaps

sound proof helmet

hard toed boot

1.1.2 Felling of trees.

Felling Objectives

Properly conducted cutting operations should ensure the safety of cutting crews and other personnel working in the vicinity of the cutting operation minimize damage to residual rees and seedlings, especially those that are expected to make up the population of future crop trees

- minimize damage to soils and streams;
- maximize the volume of wood that can be profitably utilized from each felled tree;
- maximize the value of the logs prepared for extraction;
- facilitate extraction activities.

Potential consequences of improper cutting operations

Improper felling operations may result in:

- a poor safety record and high insurance or compensation costs;
- high cutting costs;
- low utilization rates;
- low profitability from improperly crosscut logs;
- inefficient and costly extraction due to the haphazard placement of tree stems rather than their correct alignment with respect to extraction routes;
- excessive damage to residual trees and seedlings;
- excessive damage to soils and streams;
- poor post harvest condition of the forest that does not meet silvicultural objectives;
- infestation of the site by pioneer species or vines.

Recommended practices

- In cutting operations, the first consideration must always be safety. This implies that all members of the crew must be in good health and that continuous training and close supervision are essential. Details of safety and health aspects of felling operations and other forest work are provided in publications such as *Chainsaws in tropical forests* (FAO and ILO, 1980) and *Fitting the job to the forest worker* (ILO, 1992).

- Cutting must only be done by competent personnel outfitted with appropriate safety gear and using properly maintained equipment. Most cutting worldwide is done with chainsaws. These are inherently dangerous tools that are easily mishandled by persons not thoroughly acquainted with their proper use. By far the largest number of logging accidents occurring annually is associated with chainsaws.

- In some areas, manual tools such as crosscut saws are still commonly used in cutting operations. Properly used and kept in good condition, these are perfectly good tools that can be far more cost-effective in many developing countries than chainsaws. Even such simple tools can be very dangerous, however, and their use requires proper training and supervision.

- There are very few situations in which axes or other chopping tools can be used efficiently for felling or crosscutting trees. Such use causes an enormous waste of wood. Axes are excellent tools for removing limbs and cutting underbrush, but they should not be used for felling or crosscutting. Any perceived savings from such use are purely illusory. Saws, which produce only a thin kerf of sawdust, are always preferable to chopping tools, which inevitably convert a large volume of usable wood into chips.

- Where selection harvesting is being used, trees to be harvested should be marked before cutting begins. The detailed harvesting map prepared during the planning stage should be taken into the field and used to help decide which trees are to be removed. This information should be noted on the map for use by the harvesting crews.

- The recent experience of several organizations working to develop low-impact harvesting systems for tropical forests suggests that damage to residual trees can be reduced by also marking those trees that are expected to form part of the future crop tree population. Doing so provides visual reinforcement for the felling and extraction crews concerning those trees that should be protected whenever possible.

- In forests where climbers tend to bridge across tree crowns, the climbers should be cut well in advance of the cutting operation so that they will die and become brittle. This reduces the chance of a felled tree pulling over neighbouring trees as it falls. Climber cutting can often be done at the same time as the trees are being marked for felling.

- The planned direction of fall should be indicated on the bole of each tree to be harvested. In general, trees should be felled either towards or away from skid trails or cableways, preferably at an oblique angle to the skidding direction (between 30° and 45° is often suggested as the "optimal" angle range unless trees can be felled directly on to the skid trail or cableway). Felling away from the skid trail or cableway will reduce problems for the extraction crew when tree crowns are large, but felling towards the skid trail or cableway can reduce the extraction distance substantially. The decision whether to direct trees towards or away from the skid trail or cableway will depend upon local experience, terrain conditions and the type of logging system being used as well as other factors.

- Wherever possible, trees should be felled in the direction of existing canopy gaps in order to reduce damage to nearby standing timber. Trees near a skid trail or cableway should be felled so that their crowns fall alongside the skid trail or cableway for easy extraction.

- It is often desirable to direct the tree being felled towards the crown of another tree that has been felled previously. This cushions the impact, reduces the area of forest damaged and helps bunch the logs to improve skidding efficiency.

- On steep slopes, trees should not be felled directly down the slope unless their downhill lean is so great that directional felling techniques are unable to pull the tree into another direction. Felling laterally across the slope or along the contour will reduce the tree's momentum and thus minimize breakage of the felled tree and damage to neighbouring trees. To prevent a tree from rolling downhill after it has been felled, it should be lodged against the uphill side of a nearby tree if possible. This is likely to damage the second tree, but the total damage should

be substantially less than the destruction that could be caused by the felled tree's crown if it were to roll or slide down the steep hillside.

- Where social conditions and the size of trees permit, the use of felling or integrated harvesting machines can greatly increase felling productivity and, at the same time, substantially reduce the frequency and severity of accidents. Because of their high cost and the requirement for trees of nearly uniform size, in practice, the use of such machines is currently limited primarily to industrial plantations or to natural stands of smaller trees. They can be used effectively either for clear-cutting or for selection harvesting.

- Whenever possible, trees selected for felling within streamside buffer strips, where this is permitted, should be felled so that their crowns fall outside the buffer strip.

- In general, trees should not be felled across streams. In some countries, in fact, it is prohibited. There are instances where this may be the best option, however, because of terrain and safety considerations. When trees are felled across or into streams, extraction must be undertaken carefully in order to minimize damage to stream banks and streamside vegetation.

- To maximize the volume and value of wood recovered from each tree, cutting crews should be trained to follow proper crosscutting procedures. This requires that the entire bole be measured prior to crosscutting and that log lengths be determined according to mill requirements. The experience of training programmes to improve crosscutting skills suggests that improved utilization of 20 percent or more and increased log values of 10 to 50 percent can be attained by such training.

-Special safety precautions must be taken whenever there is a possibility that members of the public or other persons not directly involved in the felling operations might be endangered. When felling is to be done near roadways, for instance, it is essential that a flag bearer be posted on the road to halt traffic until the tree has been safely brought to the ground.

-A large proportion of tree nutrients, especially in tropical forests, reside in the bark and foliage. Removing the limbs and bark at the felling site will thus leave nutrients in the forest, contributing to improved growth in the new crop of trees. However, it is not always practical to remove the bark at the felling site; this will depend upon labour costs and the ease with which the bark can be separated from the wood. Also, for some species, the bark may be needed to help protect the log from abrasion or the wood from insect and fungal attack, or to prevent the log from splitting as a result of drying out while being stored prior to processing.

Commencement of felling

Examine the tree and its surroundings

Note any uneven distribution of branches in the tree crown, lean of the trunk and signs of rot or decay. Inexperienced tree cutters should never attempt to cut trees that are decayed or rotted inside or that are leaning or otherwise under tension. Such trees are at greater risk of snapping or splitting while being cut, which could cause serious or fatal injury to the cutter or bystanders.

If power lines are in the vicinity of the tree, do not attempt to fell the tree unless you are absolutely certain that doing so will not interfere with them. If the tree must be removed and

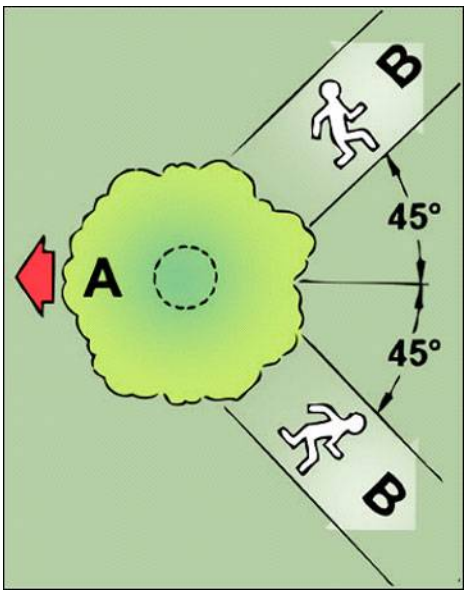
you suspect felling it will affect a power line, call the power company. They will have the expertise and equipment to remove the tree safely.

Examine the tree for loose, dead limbs. Loose limbs that fall onto the tree cutter are a common cause of serious injuries and fatalities. Remove loose limbs before felling, if possible. If that's not possible, fell the tree from a position where the limbs could not strike you if dislodged.

Note the position of nearby trees. Be sure that the tree you are felling can fall all the way to the ground. A lodged tree is very dangerous. Experienced loggers are often killed by felled trees that hang up or snag in adjacent trees. A tree spring-back from the weight of a falling tree can whip a broken limb toward the cutter or bystanders with tremendous speed.

Plan two escape paths

Plan two escape paths (B) opposite the planned direction of the fall of the tree (A) and at about a 45 angle from each other (Figure 1). Remove all obstacles from the paths. Place all tools and equipment a safe distance away from the tree but not on the escape paths. Select a place to set the chain saw in case of emergency. Never run while holding a chain saw, operating or not. Rather, turn off the chain saw and set it down before making your escape



When preparing to fell a tree, plan two escape paths. Clear the paths of all obstacles before making your first cut.

6 steps to successful tree felling

1. Plan ahead

When it comes to tree removal by using a chainsaw, preparation is key. If you plan the felling and which forestry equipment to bring, not only are you in for a safer working session, but your post-felling work can also be a lot easier. First of all, ask yourself if there are any major obstacles – such as overhead lines, roads or buildings – in the area. Deploy warning signs if you know that a road crosses the forestry area or that a lot of people pass by on a daily basis.

2. Check the felling direction

Continue by determining the felling direction by carefully studying the tree. How do the branches look and how do they grow? Also, take the wind direction into consideration. If you're unsure of the tree's natural direction of fall, step away from the tree and check with a plumb line (see fact box for details). Clear around the tree in the intended felling direction. Also clear about 45 degrees behind the tree in both directions, creating your path of retreat.

3. Prune the trunk

When you have cleared the area, put up your warning signs and decide on the tree's direction of fall and your path of retreat. You should check that you have enough fuel in the tank for the task ahead. Then it's time to prune the trunk to get rid of all the branches and twigs that might get in the way when sawing the felling cut. The safest way to prune is to work with a pulling chain (underside of the guide bar) from the top down.

4. Decide on cutting technique

Once the trunk is twig-free up to shoulder height, it's time to make the felling cut. When doing this, it's important to remember two things: the hinge should have a uniform thickness with the right dimensions and the felling wedge or breaking bar should be inserted before the tree can pinch the guide bar. Which technique you should use for making the cut depends on the tree size and slope, and on the size of your chainsaw. We have put together information about the different techniques here; so that you can find out for yourself which method best suits your conditions. /insert link to proper passage in "working with chainsaws"

5. Check for diseases

If you notice that the timber is discoloured and soft or if the lower part of the trunk looks swollen or diseased, you need to be very careful. This is an indication that the tree is infested with rot and that means the wood fibres are weakened. When this happens, fell in the tree's natural direction of fall and use a winch if you are unsure. Rot infestation usually subsides higher up in the tree, so one option might be to fell the tree with an extra high stump.

6. Choose your tool

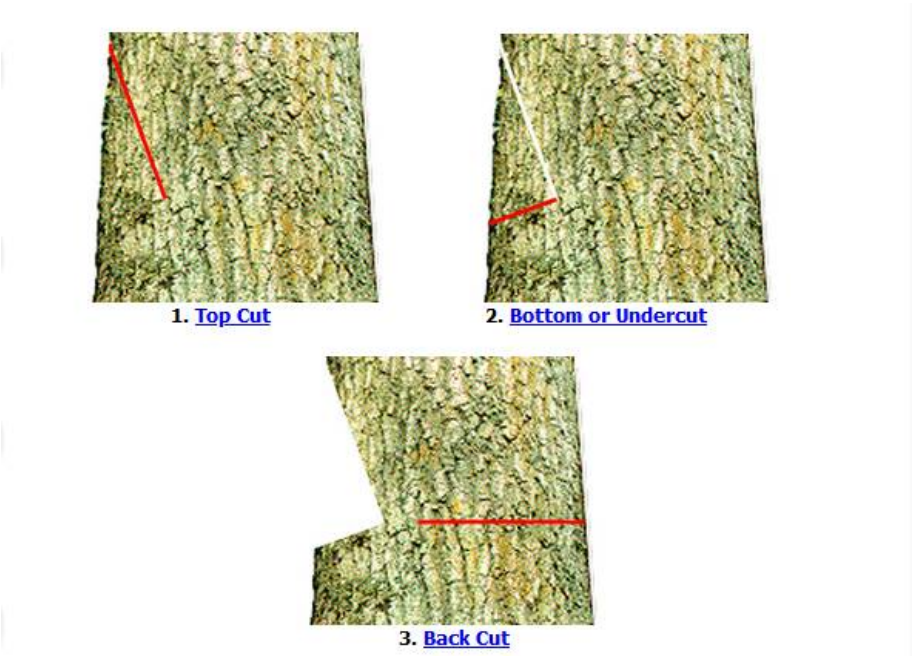
There are several felling tools to choose from when taking the tree down. The size of the tree determines which type of forestry equipment you need. For the smallest trees, you do not normally need the felling tools. Hand force is enough, possibly with the help of a long pole. The felling wedge provides greater felling force than the different types of breaking bar. In extreme cases you can use a rope and a winch, which is the safest and most powerful way to fell a tree. Have a look at the fact box for more information about the different tools.

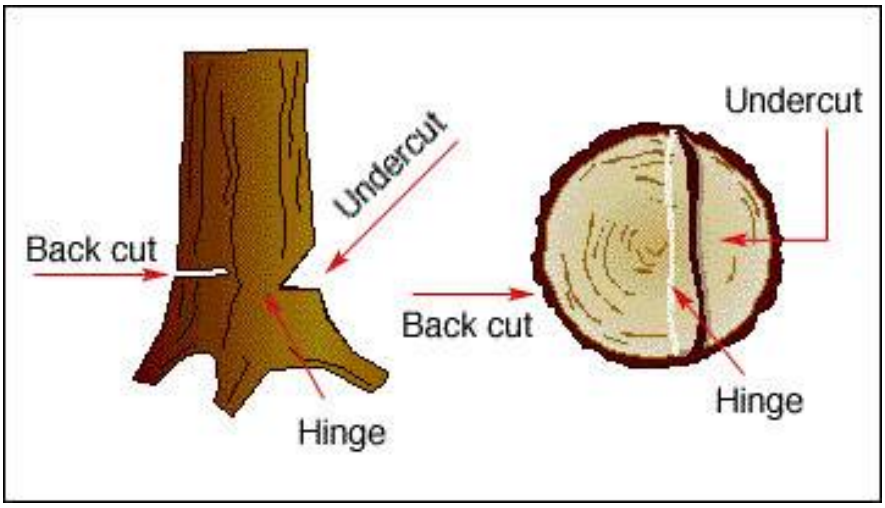
Making the cut

The safe felling of a tree includes making three precise and strategic cut.

Undercut

- The undercut serves as the guiding or aiming slot for the tree. Basically it is a V-shaped notch placed on the side of the tree in the direction of falling. Typically the first cut is made parallel to the ground and then the slanting cut is made.
- Ensure all bystanders are a safe distance from the base of the tree to be felled, at least 1-1/2 times the height of the tree, before the first cut is made.
- The undercut serves as the guiding or aiming slot for the tree. Basically it is a V-shaped notch placed on the side of the tree in the direction of falling..
- For trees that are essentially straight, the depth of the undercut should be about one-fourth of the tree's diameter.
- Back cut is made on the opposite side of the tree, slightly above the hinge point of the undercut. The back cut releases the stresses on the back of the tree, allowing the tree to fall. Never make the back cut lower than the undercut because that reverses the roles of the two cuts. Never cut through the undercut because that will cause you to lose all control over the tree.
- As the saw nears the undercut, leave a small amount of wood to serve as the "hinge" or "holding" wood. The tree actually pivots on this hinge, and the width and angle of the hinge can be used to guide the direction of the tree's fall. Because of the angled hinge, the tree will start to fall on the narrow section of the hinge while the wood at the thicker section of the hinge is still intact. The tree is therefore pulled toward the thick section. Making these cuts is an art and requires practice.
- Once the tree starts to fall, turn off the saw and move down your chosen escape path. Do not stand at the base of the tree to admire your work. Falling trees have been known to bounce backward over the stump and injure an unwary operator.





Delimbing a tree

When removing unwanted limbs from standing timber, the basic safety rule is: Never limb above your shoulders; that is, do not attempt to cut off branches above the height of your shoulders. Cutting above your shoulders requires that you hold the chain saw at or near arm's length, and you lose control over the saw in this position. Proper limbing techniques to reduce damage to the tree are covered in MU Extension publications G5160, Pruning Forest Trees, and G6866, Pruning and Care of Shade Trees.

When limbing a tree that is lying on the ground, other safety rules apply. The first thing you should do is evaluate the fallen tree. If the tree has become lodged or wedged in adjacent trees and has not fallen all the way to the ground, do not walk underneath the tree. It may fall without warning. Trees that are "hung" are especially dangerous and need to be removed by mechanical means. They can be pulled down with a cable and a tractor suitably equipped to protect against roll-over and falling objects.

Besides checking whether the felled tree is hung, also consider the following questions as you survey the area:

- Do you see smaller trees that have been bent over and trapped by the felled tree?
- Do you see branches holding the tree partially in the air?
- Is the tree on level ground?
- If you have just felled the tree, are there dead branches or other debris hanging above you that may still fall to the ground?

Dead branches and debris are called widow makers for good reason. They have been known to fall several minutes after a tree has been felled and severely injure or kill saw operators. To be safe, wait a few minutes to allow any additional debris to fall to the ground. Use the time to take a short rest.

Once you have evaluated the obstacles and hazards and are ready to limb the tree, stand on the uphill side of the tree. Never stand on the downhill side of a fallen log. If you cut a branch that is holding the log in place, the log could roll downhill and trap you. Make sure

you have good footing and are standing in a balanced position that allows you freedom of movement

Start at the bottom of the tree and work your way to the top, removing branches on the opposite side of the tree from you as you go. Whenever possible, always cut on the side of the log opposite from you. This places the log between you and the saw and provides additional protection for you.

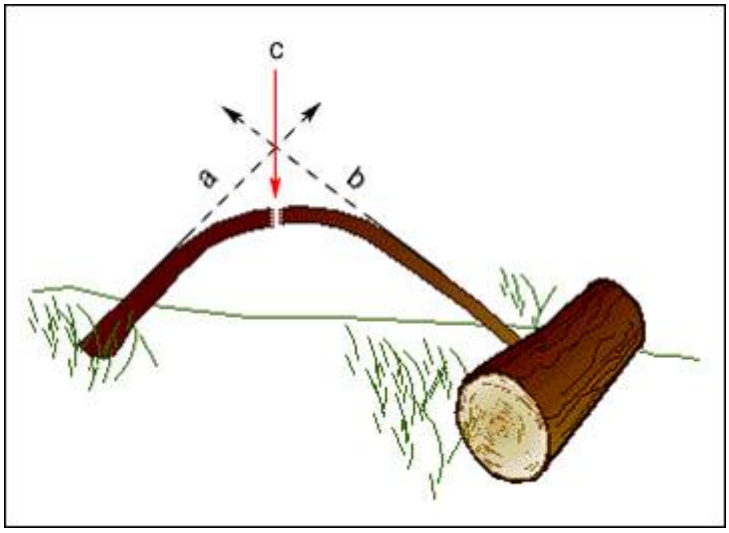
Keep sight of the tip of the saw to prevent kickback. Periodically put down the saw and remove debris so you have clear vision and movement around the tree.

Try to cut the limbs off as flush as possible with the trunk of the log. Doing this makes the log much easier to roll or move. If the limbs are in a position where flush cuts are not immediately possible, remember to remove the branch stubs later.

Depending on the species and size of the tree you are limbing, some of the branches may be very heavy. When heavy branches are removed from a log, the log may shift its position unexpectedly.

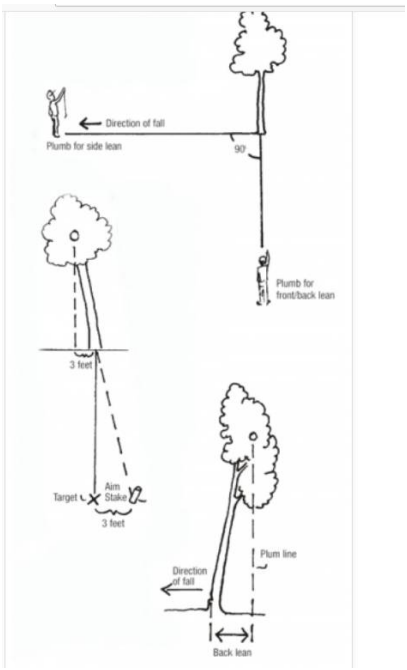
Smaller trees that are bent over and trapped by the weight of the fallen log are called spring poles. Spring poles have a tremendous amount of stored energy and present one of the greatest hazards of the limbing process. This energy can be safely removed by using an axe or chain saw to cut the spring pole at the apex of its bend. Figure illustrates how to locate the apex of a spring pole. Trapped branches can also be spring poles and can be dealt with in the same way.

When cutting a tree into firewood, you may want to start at the top of the tree so that some of the branches are off the ground. That way, the wood drops to the ground and the saw is kept away from the ground as much as possible. Again, this is a time when good footing, good balance and ease of movement are especially important.



FELLING TREES AGAINST THEIR LEAN

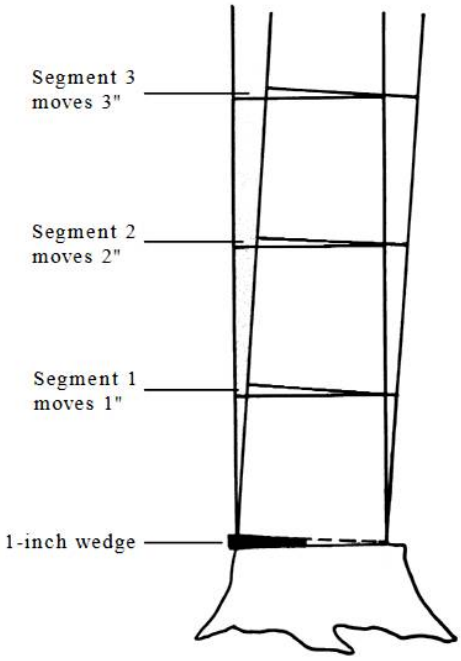
It is usually easiest to fell a tree in the direction that it's leaning, but sometimes it's necessary to fell it in the opposite direction. A tree leaning away from the intended direction of fall has "back lean." By using wedges and shims to lift the trunk off the stump, you can compensate for the back lean and bring the tree up and over in the intended direction.



Once you have established the direction of fall, you can calculate the amount of back lean that must be overcome and the amount of lift necessary to do so through some simple calculations. While standing away from the tree, at a position 90 degrees to the direction of fall, sight up to the top of the tree using a weighted string or an axe as a plumb and note the location on the ground. The back lean is the distance from this point along the intended direction of fall to the apex of the planned undercut. The apex will be the front of the hinge and the pivot point for the falling stem. The weight of the tree must be brought over this pivot point before the tree will fall. In the 60-foot-tall tree at right, the back lean is three feet.

Next, figure the diameter of the stump by measuring from the front of the hinge to the back edge of the tree (see illustration). The stump diameter is used to determine the number of segments in the tree; one segment is a section of the tree with a height equal to the stump diameter. Thus, the 60-foot-tall tree with an 18-inch stump diameter has 40 segments (720 inches divided by 18 inches equals 40).

If you raise the back edge of the lowest segment one inch, you will move its front edge one inch forward. At the same time, the top of our 40-segment tree will move forward 40 inches, enough to overcome its 3-foot back lean. If the same tree had a back lean of 4 feet, it would require 1 ¼ inches of lift (48 inches divided by 40 sections = 1.2 inches) to overcome the lean. When calculating the lift, be sure to add in the 3/8-inch saw kerf, which means that one inch of lift will require 1 3/8 inches of wedge



A combination of wedges and shims can be used to give you more lift. Cut discs of ½-inch to an inch in thickness from hardwood branches for the shims. Do not taper the discs, as that will make them weak and liable to break in the notch. Using two wedges, side by side, drive one home so that there is a gap between the stem and the top of the other wedge. Place a shim in the gap above the free wedge until it is snug, and then pound in the shim by

driving the wedge. This should either fell the tree or free up the other wedge for a thicker shim. Repeat this process with increasingly larger shims until the tree comes up over the pivot point, and then gravity will take care of the rest

Trees with heavy forward lean

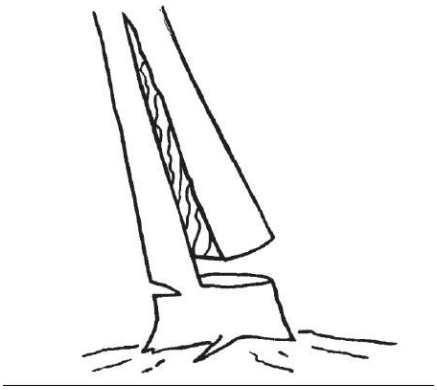
The following trees are difficult to fell safely using conventional methods:

• Trees that have very heavy forward lean.

• Trees with more head weight in the felling direction.

• Species prone to slabbing

Using a conventional scarf and back cut on heavy front-weighted trees is dangerous. As a conventional back cut is made, high tension forces in the uncutwood create a split or "Barber Chair". If this happens it may lose control, and it may slide backwards off the stump.



"Barber chair"

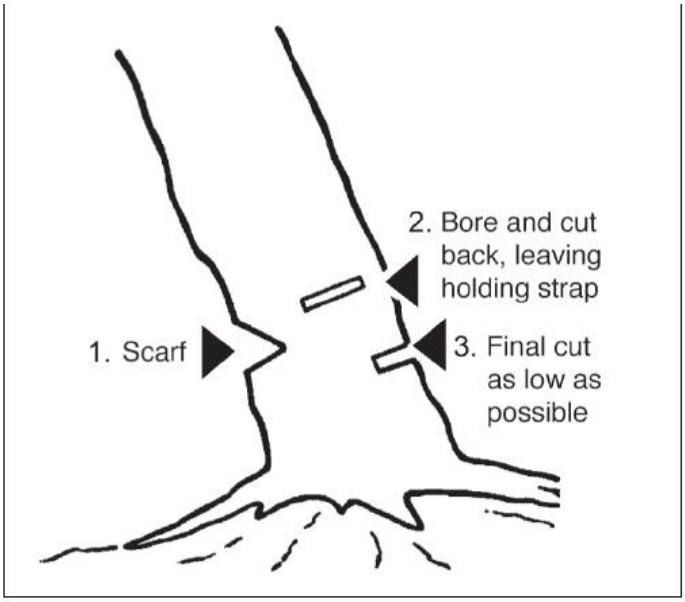
Use the following bore and release method to reduce the chance of a heavy-leaning tree splitting:

(1) Cut a conventional scarf slightly higher than you normally would. Make the scarf shallower than normal

(2) Remove the bark from the back of the tree so that the solid anchor wood can be gauged. With very heavy forward-leaners, **do this carefully!**

(3) Start the bore cut well behind the scarf.

(4) Cut forwards towards the scarf to establish the hinge. The boring cut must be made from both sides of the tree if the bar is not long enough. **Don't go too far forward or you will risk getting your saw jammed**

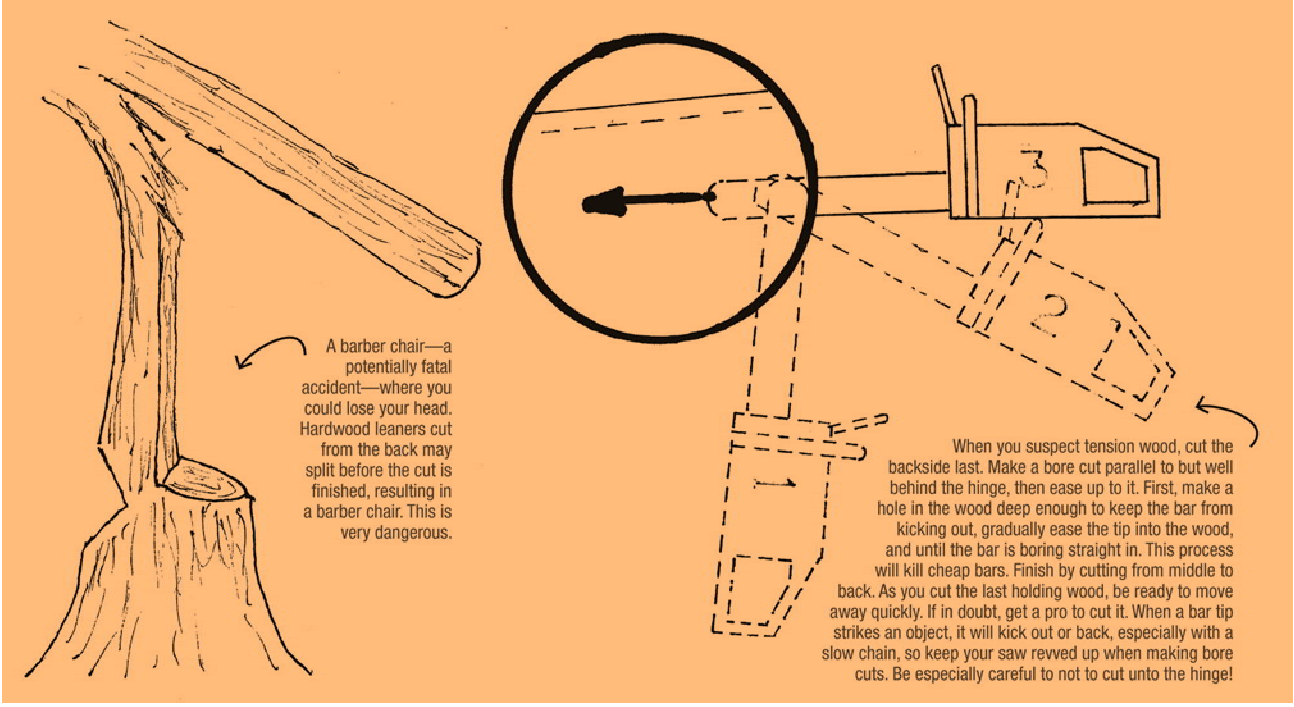


Bore and release cuts for a heavy forward-leaning tree

(5) When you have cut to the hinge wood, cut towards the back of the tree leaving sufficient wood uncut to act as an anchor (holding strap).

(6) Do not go in front of or behind the tree once the bore cut has been made!

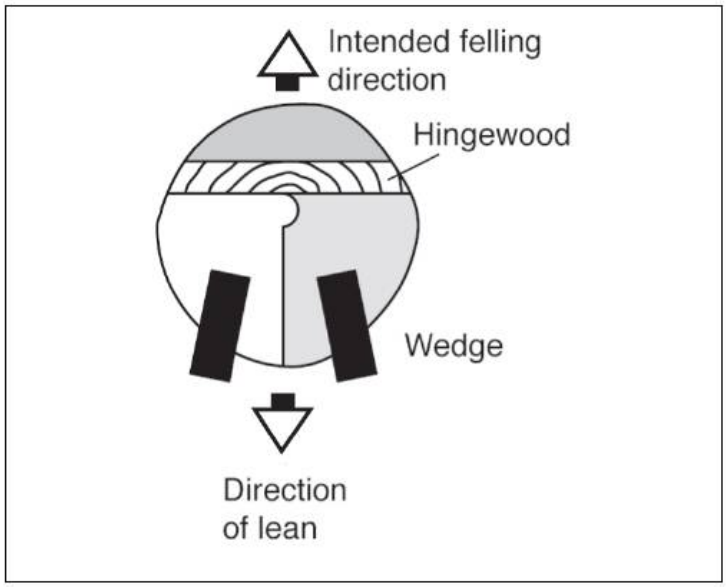
(7) Start the final back cut to release the anchor wood, cutting from the back of the tree. Make this cut below the level of the bore cut. The lower the final release cut, the slower the tree will fall.



(8) As the anchor wood is cut, watch for signs that the tree is falling. **Be aware that the tree will fall very quickly.**

If the tree diameter is small, the bore cut may cut the holding strap at the back of the tree. In this case, angle the bore cut to reduce its effective width.

Large trees (where the bar does not go right through the tree)



Use the quarter cut

(1) Cut a conventional scarf according to where you want the tree to fall.

(2) Make the first cut of a quarter-cut back cut.

(3) Insert a wedge into the first quarter-cut and set firmly

(4) Ensure you do not over-cut the hinge wood.

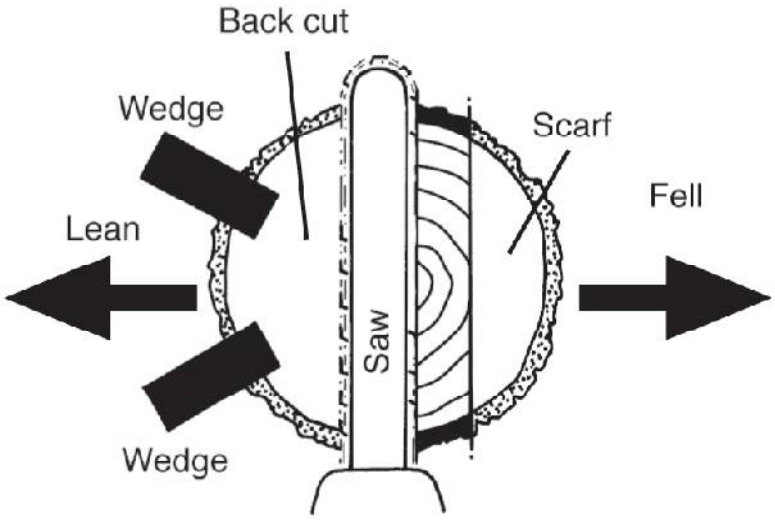
(5) Start the second quarter-cut and ensure both cuts overlap.

(6) When far enough forward, insert a wedge into the second quarter-cut.

(7) As you progress with the second quarter-cut, stop to drive the wedges.

(8) Complete the second quarter-cut. Stop your saw, and drive the wedges alternately until the tree begins to fall.

Medium-sized trees (where the bar does go right through the tree)



(1) Cut a conventional

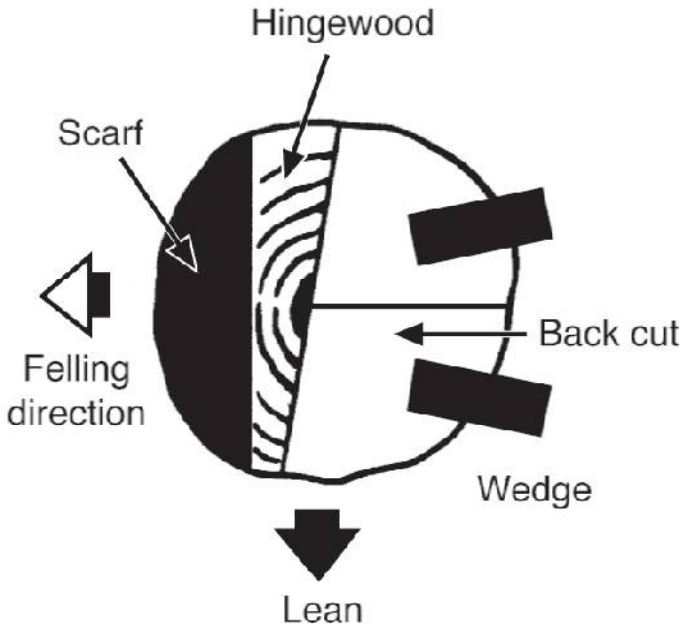
scarf according to where you want the tree to fall.

(2) Start a conventional back cut, cutting from the back of the tree towards the hinge wood. When the bar is far enough into the cut, insert one or two wedges into the back cut.

(3) Continue the back cut, stopping a couple of times to drive the wedge(s) in more.

(4) Stop your saw when the hingewood is reached and drive the wedge(s) until the tree begins to fall.

Felling trees with side lean



The method used will depend on the degree of side lean. For heavily side-leaning trees, machine assisted methods are more appropriate

Assess predominant and side lean to identify the safe side of the tree. Where the side lean is slight, wedges and a variation in hinge width can be used.

(1) Make the scarf facing the intended direction of fall.

(2) Make a wing cut on the downhill side of the hingewood only.

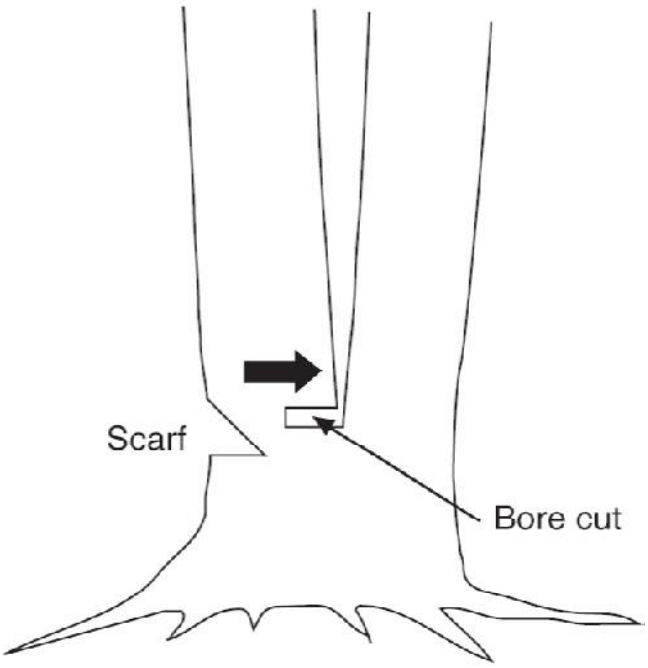
(3) The back cut is made as a quarter cut. The hingewood width on the lean side of the tree is slightly less than normal. Start the first quarter cut on the leaning side of the tree.

(4) Insert a wedge in the first quarter cut when it is completed.

(5) Start cutting the final quarter cut. Tap the wedge in further as the cut is made. Stop the cut when you reach the hingewood. Remember to leave a wider hinge on this side of the tree.

(6) Drive the wedge home, and the tree should fall in the right direction.

Felling multi-leader trees



Whenever possible, each leader on a multi-leader tree should be felled separately in the direction of its lean.

When the dividing point of the leaders is close enough to the ground to be reached safely do the following:

(1) Put a normal scarf in the first leader, facing the direction of lean.

(2) Bore in behind the scarf at the correct height, leaving the required amount of hingewood.

(3) Cut back towards the dividing point of the leaders. Slow the back cut near completion, as the leader will fall very quickly.

(3) When the first leader is safely felled, the remaining one can be felled normally.

(5) Cut the stump off at ground level.

Each leader needs to be considered as a tree and felled accordingly. **Felling the first leader**

Bore and release cuts for a heavy forward-leaning tree

Note that it may be unsafe to trim the first leader until the second is felled. This will depend on the lean and condition of the standing leader.

If the dividing point is above shoulder height, then fell the two leaders as one tree.

(1) Scarf the tree deep and wide enough to cover both leaders. It must be made in solid wood without a join or fault line running through it.

(2) From the safest position, make the back cut evenly towards the holding wood.

(3) Use wedges to ensure that both leaders start falling together

Assisted felling procedure

Situations may arise where some trees cannot be safely felled by a chainsaw alone.

These trees may include:

• Very large trees

• Edge (boundary) trees

• Trees adjacent to environmentally sensitive areas • Hung-up and cut-up trees

• Heavily leaning or very malformed trees

In many cases, these trees need to be felled in the opposite direction to the natural lean or crown weight of the tree.

In these circumstances there are several techniques that can be used. These include the use of the following

machines to assist in felling:

• Hydraulic tree jacks

• Cable hauler (or swing yarder)

Felling with hydraulic tree jacks Rules

Using two jacks for large trees

Follow the steps below when using two jacks:

(1) Make the scarf cut (Cut 1). It should be no more than 1/4 of the tree diameter.

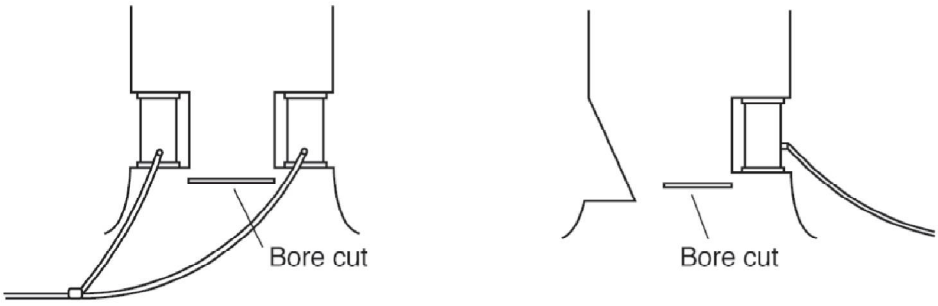
(2) Measure and mark where the blocks are to be removed from the back of the tree. The Bottom horizontal cut is part of the back cut. It should be stepped up from the scarf an extra 50 mm on what you would normally do.

(3) Cut out the blocks taking care not to cut more of the holding wood than is necessary (Cuts 2 and3). You need a good amount of holding wood to prevent the tree sitting back before the jacks are seated and the tension taken up.

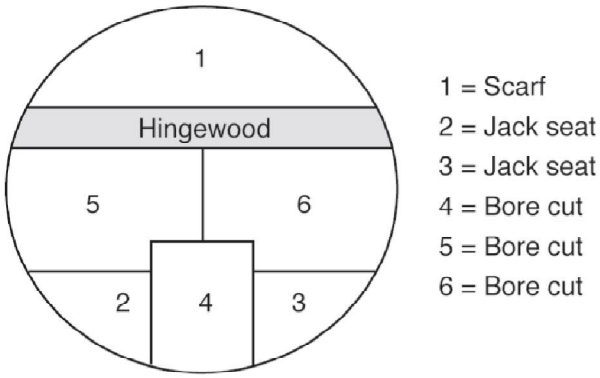
(4) Insert the jacks, making sure that the top and bottom jack plates are sitting on wood and not overlapping on to bark.

(5) Pump the cylinders up to approximately one-third of the maximum pressure.

(6)Bore cut the holding wood at the back of the tree (Cut 4). Make the cut slightly lower than the jack base plates.



Back view Side view



(7) Bore cut the holding wood from one side of the tree between a jack and the Hinge wood (Cut 5).

Do not cut under the jack cylinders.

(8) Make the final bore cut from the opposite side of the tree (Cut 6). The cutting up procedure is now complete. **Insert the jacks Making the final bore cut**

(9) The chainsaw operator should now stand clear watching the top of the tree for movement while he jack operator pumps up the pressure.

(10) The jack operator should be watching the pressure gauge.

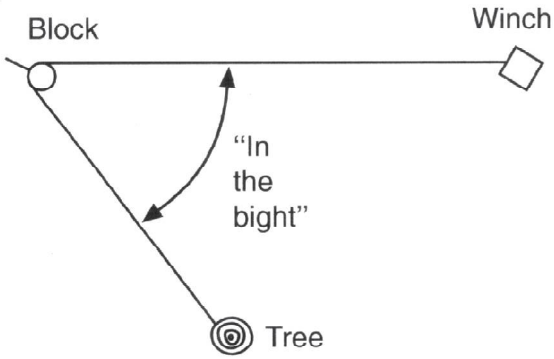
(11) Both operators should work in unison while the tree is felled.

Cut out the blocks **Making the final bore cut** **Insert the jacks**

Back pulling trees Equipment

• The winch rope and strop must be of sufficient length and breaking strength to ensure safe positioning and purchase to pull the tree in the desired direction when the felling cuts are completed.

• The pulling strop when positioned on the tree should be of sufficient length to hang within reach from the ground for connecting the winch rope.



The bight in the winch rope

• Eye-to-eye splices should not be used in any pulling rope. Joining with splices considerably reduces the rope's safe working load.

• Do not use knots in any wire rope.

• Ropes, blocks, and shackles must be of sufficient safe working load (SWL) and condition to handle the job in hand.

• Never allow people to work or stand "in the bight" of an operating rope.

Winching

• Work out your visual and vocal communication before you start the work.

• Use sound stumps of sufficient size for the job in hand.

• Strops used on stumps should be at least 1.5 times the safe working load (SWL) of the pulling rope and should be notched so they do not slip off.

• Machines used must have sufficient weight and winching power to control the tree to be felled. They should be equipped with ROPS and FOPS to protect the operator from roll over or falling objects.

• Make sure all the equipment you need is on site.

Back pulling against the tree lean (no blocks)

The winch rope may be used directly off the pulling machine only if the machine can be positioned at least two tree lengths from the tree to be pulled or positioned where there is no risk of being struck by the falling tree. Follow the steps below when back pulling directly off the winch:

(1) Before any work begins, discuss fully with yourco-workers what you intend to do. Winch and machinery operators must know what is required in relation to line tension and pulling speeds.

(2) Secure the rope as high as practicable on the tree. This may require a ladder.

(3) Position the pulling machine in the intended direction of fall. It must be at least two tree lengths from the tree. Engage the park brake and place the blade down.

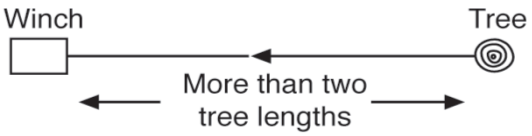
(4) Tension the rope to hold the tree in position.

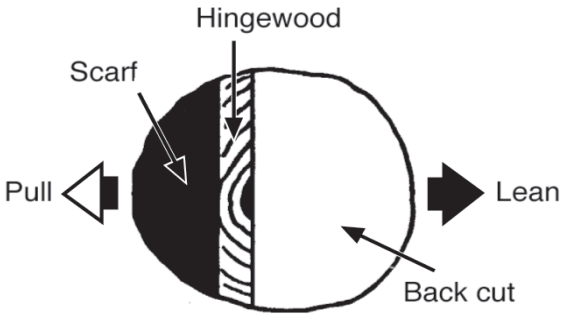
(5) Scarf the tree in the normal manner.

(6) Back cut the tree in the normal manner, ensuring adequate hingewood is retained. Use wedges to hold the back cut open if necessary.

(7) Retire to a safe position and signal the pull to commence.

(8) Pull slowly with the winch at first, and then increase speed until the felling cuts take control.





Back pulling against tree lean (no block)

Back pulling against the tree lean (using a block)

If you cannot get two tree lengths from the tree (in the direction of fall), a block can be rigged to alter the pulling direction. This method positions the winch and operator in a safe position. It also allows good vocal and visual contact.

The method requires a suitable stump in the intended direction of fall. A large block is anchored to the stump and the winch rope is run off the drum, through the block, and connected to the tree.

Follow the steps below when back pulling using a block:

(1) Before any work begins, discuss fully with your co-workers what you intend to do. Winch and machinery operators must know what is required in relation to line tension and pulling speeds.

(2) Locate an adequate stump in the intended direction of fall. Ideally, the stump should be more than one tree length away to make de-rigging the block easier.

(3) Notch the stump, and fit a block strap. Connect the block to the strap using a shackle.

(4) Pull the winch rope off the drum, through the block and back to the tree to be back pulled.

(5) Secure the rope as high as practicable on the tree. This may require a ladder.

(6) Locate the pulling machine in a safe position, preferably out to the side of the tree. Engage the park brake and place the blade down.

(7) Tension the rope to hold the tree in position.

(8) Scarf the tree in the normal manner but opposite the lean.

(9) Back cut the tree in the normal manner, ensuring adequate hinge-wood is retained. Use wedges to hold the back cut open if necessary.

(10) Retire to a safe position and signal the pull to commence.

(11) Pull slowly with the winch at first, and then increase speed until the felling cuts take control

Back pulling a side leaning tree

Modifying the hinge wood width can allow the controlled felling of a side leaning tree. The hinge wood should be narrow in the direction of lean.

Follow the steps below when back pulling a side leaning tree in a confined space:

(1) Before any work begins, discuss fully with yourco-workers what you intend to do. Winch and machinery operators must know what is required in relation to line tension and pulling speeds.

(2) Secure the rope as high as practicable on the tree. This may require a ladder.

(3) Identify the direction of lean, and the intended direction of fall.

(4) Position the winch 80° the other side of the fall direction. Engage the park brake and place the blade down.

(5) Tension the rope to hold the tree in position.

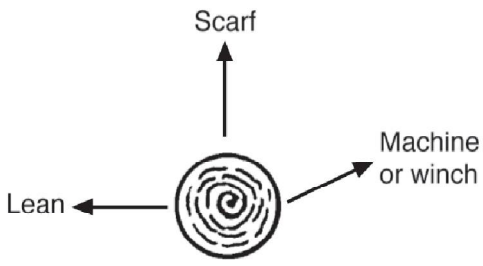
(6) Scarf the tree in the normal manner in the intended direction of fall.

(7) Make the back cut, keeping more hingewood opposite the lean.

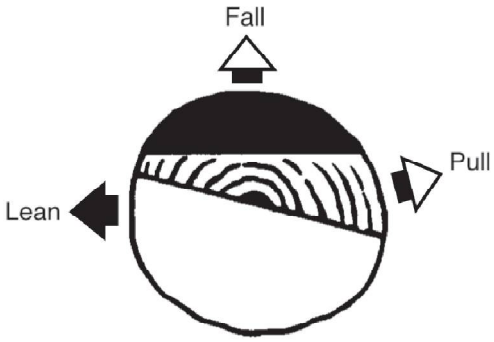
(8) Complete the back cut. Stop your saw and move to a safe position.

(9) Signal the winch operator to slowly pull the tree over.

(10) Stop winching when the felling cuts take control of the tree fall. The tree will free fall, swinging on the rope with no danger to the operator or equipment.



Back pulling a side leaning tree



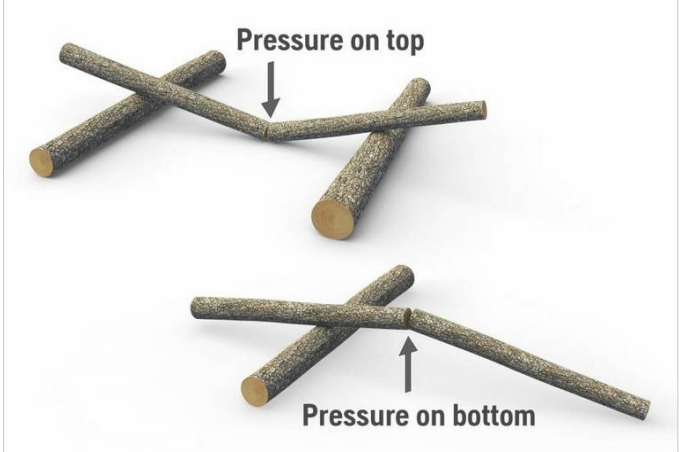
Felling cuts for a side leaning tree

1.1.3. Cross cutting

Plan the crosscutting procedure carefully, especially for larger logs. An incorrect work technique can be dangerous and cause the trunk to split or the guide bar to become pinched.

Safety when crosscutting

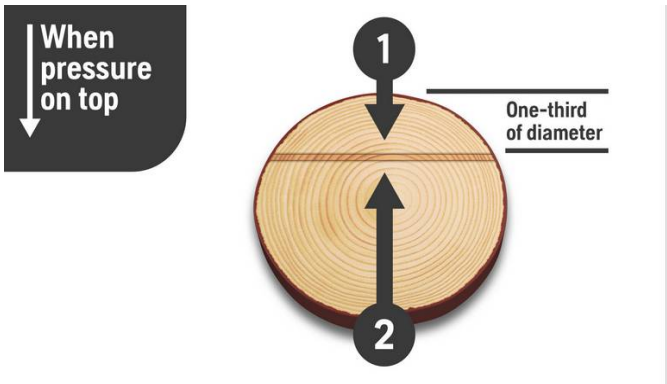
Be aware of how you are standing when crosscutting logs. Stand off to the side of the cut, as the trunk can jump up or throw back. If the ground slopes, never stand on the downhill side and crosscut. The log can start to roll before it is cut through and injure you.



Method:

Pressure on top: basic crosscutting technique

For trunks where the chainsaw's guide bar reaches all the way through:



- Start by making a cut from the top side. The depth of the cut should be about one-third of the diameter of the trunk, or before the trunk tends to pinch the guide bar.
- Now cut from the bottom to meet the first cut. Saw until the log is cut through.

Pressure on top: crosscutting thick trunks

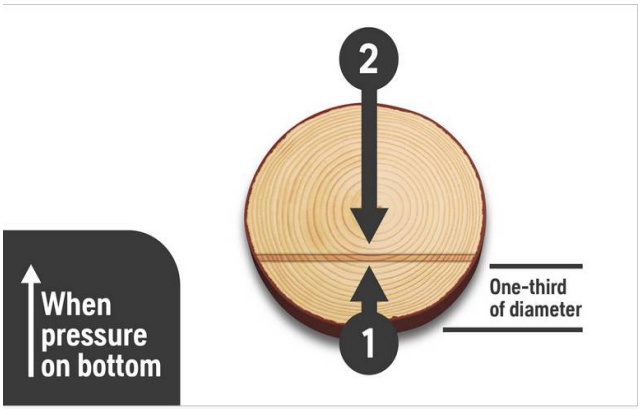
If the pressure is on top and the trunk is thicker than the bar length:

- Start by crosscutting the opposite side of the trunk.
- Pull the saw towards you and crosscut from the top, up to about one-third of the trunk diameter.
- Now crosscut from the bottom. Make a bore if the trunk is lying on the ground to avoid sawing stones.
- Continue with undercutting towards the centre of the trunk.

Pressure on bottom

When the trunk lies so that the pressure comes from the bottom, you must perform the cross cutting in a reversed sequence:

Method:
Pressure on bottom: basic crosscutting technique
For trunks where the chainsaw's guide bar reaches all the way through:



- Start with the undercut up to about one-third of the trunk diameter, or until the guide bar tends to pinch.
- Now cut from the top to meet the first cut. Saw until the log is cut through.
- method

Pressure on bottom: crosscutting thick trunks

If the pressure is on the bottom and the trunk is thicker than the bar length

- Start by crosscutting the opposite side of the trunk.
- Pull the saw towards you and cut a little from the top.
- Now crosscut from the underside, up to about one-third of the trunk diameter. Make a bore if the trunk is lying on the ground.
- Finish with a top cut.

1.2. OFF ROAD TRANSPORTATION

1.2.1 Ground skidding

Recommended practices for extraction with ground-skidding equipment

Most logging worldwide is done with ground-skidding equipment. Such equipment includes crawler tractors (bulldozers), wheeled and tracked skidders and farm tractors. The following practices are recommended when such equipment is being used:

Wheeled skidder

As a general rule, skidders are preferable to crawler tractors for log extraction. Unlike crawlers, which are general-purpose machines especially intended for use in construction and excavation, skidders are designed explicitly for log extraction. Their rubber tyres and high manoeuvrability can reduce soil and tree damage. They are usually narrower than crawler tractors and have smaller blades so that they can pass more easily between residual trees without causing damage. The smaller blades also prevent excessive blading, which can initiate erosion.

1.2.2. USE OF TRACTOR

Crawler tractor

Crawler tractors are often used in forestry for road construction and maintenance as well as for skidding. As a result, they have certain economic advantages compared with skidders, which have only one purpose. Because they are equipped with steel tracks and powerful bulldozer blades, crawler tractors can be used on very steep slopes. Also, operators tend to blade skid trails simply because it is easy to do so, rather than limit blading to places where it is required for safety or efficiency. The consequence is that unnecessary soil disturbance and excessive damage to residual trees and advance regeneration are all too common when crawler tractors are used for log extraction. In spite of their problems, however, it must be recognized that in many forest areas, particularly in steep terrain with large trees and high precipitation rates, crawler tractors are likely to remain the most common type of skidding machine used. To minimize problems when such machines are used, therefore, effective training of the tractor operators and their careful supervision are essential.

Farm tractor

The use of farm tractors is a reasonable option when trees are relatively small and the terrain is not exceptionally rugged. Because these vehicles are not designed specifically for logging, safety can be a serious problem, and modifications are almost always needed to improve the durability of the machines as well as to make them safe for forest work. With such modifications farm tractors can be an excellent choice for small, private forests or in developing countries where farm machinery is often easier to obtain than specialized forestry equipment. Farm tractors are particularly well suited for work in forest plantations, especially for harvesting smaller stems, as in thinning.

Regardless of the type of skidding equipment used, machines with an appropriate size and power configuration for the operation should be selected. The blade width should not exceed about 3 m (2 m is usually sufficient), and the machine should have a powered winch with at least 30 m of wire rope as well as an arch or other support that will suspend the end of the load off the ground to prevent logs from digging into the soil as they are being skidded.

Where soils are easily compacted, the use of low-ground-pressure skidders should be considered to reduce soil disturbance, rutting, and compaction.

A farm tractor being used to skid logs.

Tracked skidder

-These are tracked skidders with torsion suspension systems and a design that moves the load's centre of mass forward on to the skidder for better weight distribution over the tracks. Such skidders are more expensive than wheeled skidders but produce less ground pressure and, because of the torsion suspension system, tend to pass smoothly over such ground cover as logging debris and undergrowth, leaving it largely in place. Wheeled skidders and crawler tractors are more likely to crush ground cover into the soil.

- "High-flotation" tyres or dual tyres mounted on wheeled skidders may be used instead of tracked skidders for damp or easily compacted soils. Both solutions increase the effective width of the tyres where they are in contact with the ground, thus spreading the weight of the machine and its load over a larger surface area, reducing pressure on the soil.

- Skidding operations should be suspended altogether during exceptionally wet weather. Skidding during such periods increases erosion and other damage, reduces operating efficiency, increases accident rates and may double or triple operating costs.

- Steep slopes should be avoided in ground-skidding operations. Although modern skidding machines are often mechanically capable of operating on quite steep slopes, doing so greatly increases soil disturbance, reduces operating efficiency and leads to faster depreciation of the machine. Slope limits will vary from region to region depending on soil conditions, precipitation and other factors. Many countries restrict ground skidding to slopes of less than 30 percent (17°) except for short distances. Steeper slopes that are sustained over long

distances should be harvested by cable or aerial systems that have the ability to suspend logs above the soil.

- A system of designated skid trails should be used. Environmentally, skid trails are the most troublesome aspect of ground-skidding operations. In many parts of the world, the conventional approach to log skidding involves the skidding machine wandering through the forest after felling has been completed, searching for logs to drag to the landing. When a log is encountered, the operator hooks it to the machine and then drives to the landing, sometimes along the same path, but other times in a different direction that the operator believes will lead more quickly to the landing. In tropical forests, where undergrowth is often dense, the machine operator may even keep the blade down most of the time, particularly if a crawler tractor is being used, thus creating a path of deeply disturbed soil wherever the machine travels! This can result in an astonishingly dense system of skid trails. Although skid trails commonly represent 20 to 40 percent of a harvested area, several studies have found that 60 percent or even 80 percent of the harvested area was covered in skid trails after selection harvesting operations had been completed. When a designated skid-trail system is used, skid trail locations are included in the harvest plan. They are first clearly flagged on the ground before the cutting operation begins, using the topographic planning map, a compass and a device to measure slope angles. With the skid trails thus marked, the cutting crew can reduce extraction costs by aligning felled trees along the skid trails and felling damage to future crop trees can be reduced by placing the crowns of the felled trees within or alongside the skid trails whenever possible.

Wheeled skidder equipped with high-flotation tyres (1000-mm wide) to reduce tyre pressure on wet soils.

Excessive skid-trail density in a natural forest in the tropics. Such practices can lead to heavy soil erosion and sedimentation of streams. These problems can be reduced by using a system of designated skid trails and requiring skidders to remain on the designated skid trails at all times.

- Skidding machines should remain on the designated skid trails at all times. Studies in many countries, including several in the tropics, have demonstrated conclusively that it is both unnecessary and uneconomical to drive the skidder to every log; by staying on the skid trail and pulling the winch line out to the log, significant reductions in soil disturbance, soil compaction and damage to residual trees and advance regeneration can be achieved.

- Choker-setters should be trained to preset chokers, locate the best approach to the log and pull the winch line out to the log while the skidder remains on the skid trail in order to facilitate the system of designated skid trails. In conventional operations, the winch line is often wrapped directly around the log to be skidded, rather than using a separate choker cable or chain. This causes a delay during which the skidder sits idle. Pre-setting of chokers not only eliminates this delay, but it also permits easier collection of a number of logs that can be skidded simultaneously.

- Skid-trail construction with the skidder or crawler blade should be minimized. In some countries, including several in the tropics, blading of skid trails has been prohibited altogether except when necessary to ensure safety. Guidelines developed by CIRAD-Forêt and tested in West Africa, South America and Southeast Asia stipulate that skid-trail construction should be limited to hand-cutting of brush and trimming of stumps to ground level. The brush cuttings can then be placed in the skid trail to provide a protective mat over which the skidders will travel. In addition to protecting soils, such procedures can also reduce costs by eliminating the time bulldozers spend unnecessarily blading skid trails.

- Skid trails should generally be as straight as possible, curving where necessary to reach timber marked for cutting or to avoid wet or unstable soils and steep hillsides. On slopes steeper than about 30 percent (17°), skid trails should be angled across the slope rather than running straight up and down it. The skid-trail width should be the minimum feasible; 4.5 m is often recommended as an appropriate maximum width when large, heavy machines are being used. Tight corners should be avoided in order to protect trees and other vegetation standing near the skid trail

- Where feasible, uphill skidding may be preferable to downhill skidding since it tends to disperse runoff water into the surrounding vegetation, whereas downhill skidding tends to concentrate it at the landing. The logs being skidded are easier to control when the skidding direction is uphill, and there is also less of a tendency for operators to attempt slopes that are too steep for safe skidding. On the other hand, pulling uphill requires more power and the vehicles may churn the soil. Operators may also tend to use the blade more frequently to remove topsoil and improve traction. Whether to specify uphill or downhill skidding thus requires an evaluation of tradeoffs, and the decision will usually represent a compromise.

- Skid trails, as well as skidding machines, must be kept out of streamside buffers entirely. Where harvesting of trees from within buffer strips is permitted, the trees should be felled away from the stream and extracted by winching.

- Skid trails should never cross streams or gullies, unless it is absolutely unavoidable. Where this must be done, the crossing should be made at a site where there is a rock base if possible. The streambed should be protected with logs or a temporarily installed culvert.

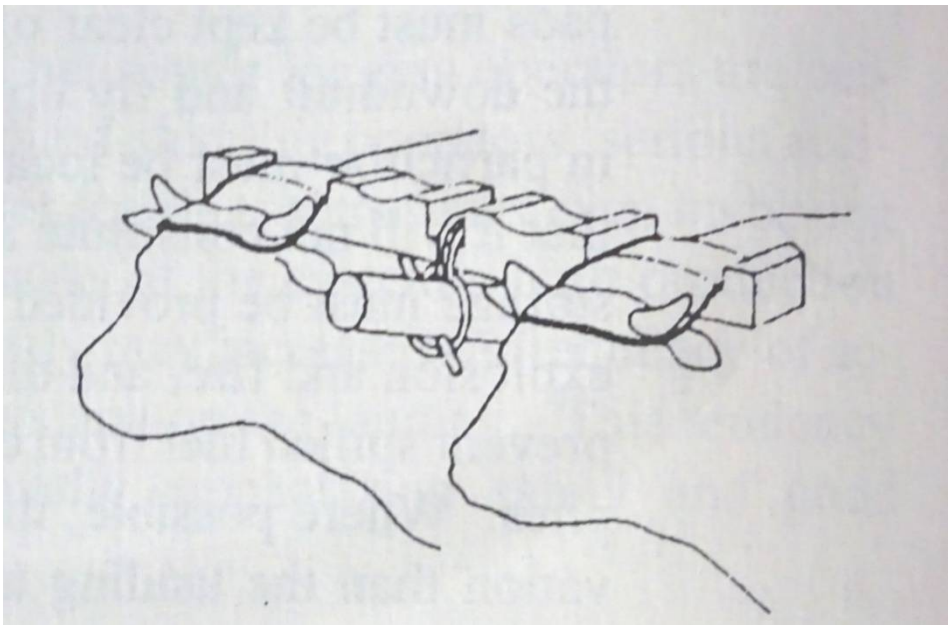
- Operators should be encouraged to use lubricating oils that are environmentally benign, such as vegetable oil, when feasible.

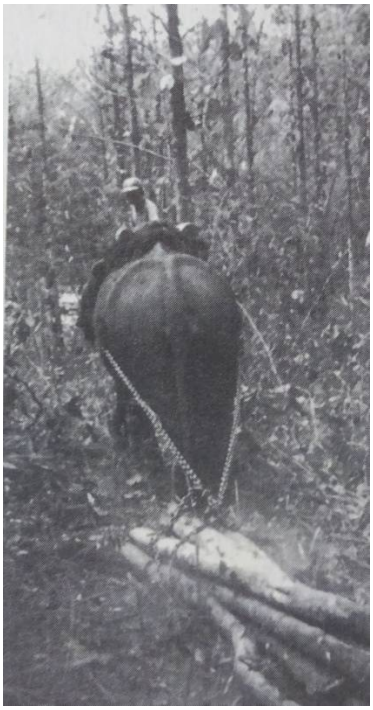
- Adequate drainage in the form of drainage ditches and cross-drains should be provided for skid trails and other areas where soils have been disturbed after the harvesting operation has been completed. These areas should be left in a state that will facilitate their rapid revegetaion. If necessary, they should be ripped up and sown with grass or other fast-growing plants.

1.2.3 DRAGGING

Dragging with draught animals continues to be an economically attractive choice in many areas, sometimes even in industrialized countries. As compared with ground-skidding equipment, the use of draught animals, such as elephants, water buffaloes, oxen, horses and mules, has been shown to reduce soil disturbance, soil compaction and damage to residual trees significantly. Direct impacts are generally limited to the extremely narrow skidding paths used by the animals. Animal skidding is particularly advantageous for thinnings or for pulpwood harvesting, where relatively small logs are to be extracted or where products from pit sawing or other onsite processing are to be transported.

Planning for animal skidding must allow for short extraction distances (typically 200 m or less) and relatively gentle slopes. Depending on the type of animal used, a maximum slope of about 20 to 30 percent (14° to 17°) is often suggested when skidding downhill and 10 to 15 percent (6° to 9°) when skidding uphill.





Head yoke for oxen logging

Elephant logging: hooking chokers to a load of logs.

Elephant logging: pulling a load to the landing.

- Proper harnesses are essential in order to prevent injury to the animals and to avoid cumulative discomfort over long working periods. Head yokes are recommended for ox teams as they avoid chafing of the skin and allow the animals' full pulling power to be employed.

- Devices such as skidding pans, sledges and sulkies can greatly improve productivity in animal skidding because they reduce skidding resistance and thus allow larger loads to be pulled.

- For operations in natural forest it is usually necessary to clear skidding paths for the animals. Undergrowth should be cut close to the ground by hand and thrown clear of the path. Obstacles that could pose a danger to the animals should be removed, and any stumps in the path should be trimmed to ground level.

- Cutting must normally be coordinated with skidding, and both should start at the back of the cutting unit (farthest from the landing) and proceed towards the landing. This avoids the animals having to climb over logging slash left behind by the felling crew.

- Animals must be fed, watered and rested at regular intervals while working or they will refuse to continue. Some animals, such as elephants and water buffaloes, require frequent baths during hot weather in order to dissipate the body heat generated by hard physical activity.

- Depending upon climatic conditions, terrain and other factors, animals may not be able to work every day and they may require relatively short working days. Often, a 20 to 25 percent reserve of animals is recommended in order to ensure that a sufficient number is available to work on any particular day.

- Although horses work quite well for log extraction in temperate climates, they are not generally suited for work in hot, humid climates such as those common to tropical forests.

-Regular veterinary care is essential whenever draught animals are used in forest work, and feeding practices must ensure that the animals' nutritional requirements are being met fully.

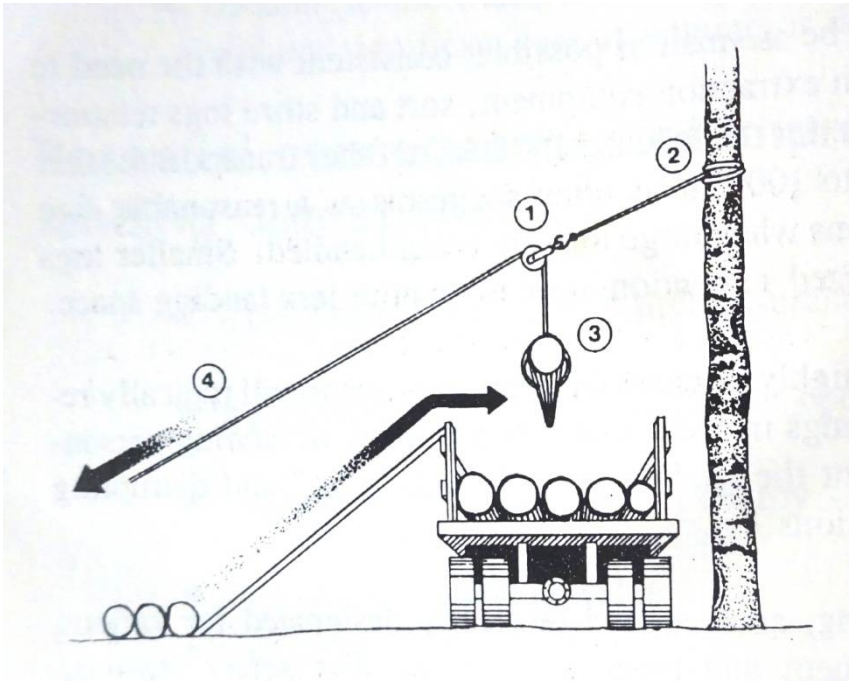
- After the skidding operation has been completed, skidding paths should be examined and, where necessary, cross-drains should be constructed to divert water from the paths into the surrounding vegetation.

1.2.4. WINCHES

Extraction by winch truck

A common extraction method in some parts of the tropics uses light trucks with powered winches to load logs for transport right at the cutting site. A low-grade hauling road

is usually cleared manually so that the truck can be driven up to the tree. Logs are loaded on to the truck with the winching system, and the truck is then driven to the next cutting site. This process continues until a full load is obtained. The truck is then driven directly to the final destination or to a landing where the logs can be consolidated into larger loads for transport by heavier trucks. Under the right soil and terrain conditions, winch-truck extraction can be a relatively low-impact system. Soil disturbance and damage to residual trees are typically less than when crawler tractors are used, for example. In general, however, the system should not be used in swampy areas or on steep slopes.



1.Pully

2. Support cable

3.Log loading tongs

4.Lifting cable attached to a powered winch

1.2.5 ARIEAL TRANSPORTATION

Aerial extraction systems

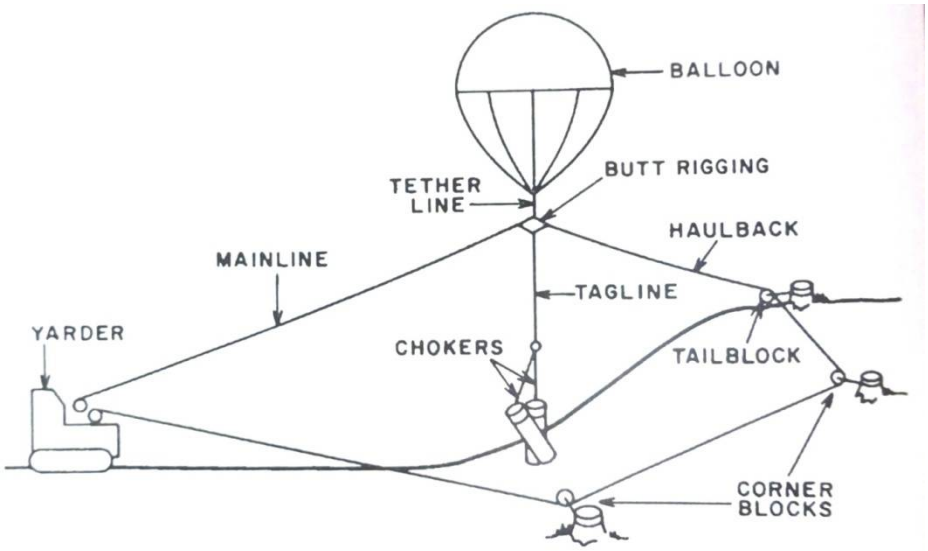
Balloon extraction systems
Helicopter extraction systems

Aerial extraction systems are those that fully suspend logs in the air throughout the entire extraction process. Skyline cable systems do not meet this criterion in general, because they do not normally suspend logs during the lateral phase of yarding, and the logs may also occasionally drag along the ground at intervals during main yarding, even when full suspension is intended, depending upon the length of the logs and the amount of clearance between the ground and the skyline cable.

Two types of aerial log-extraction systems are currently in use: balloon systems and helicopter systems. Several others have been proposed, but thus far they have not got past the experimental stage.

Balloon extraction systems

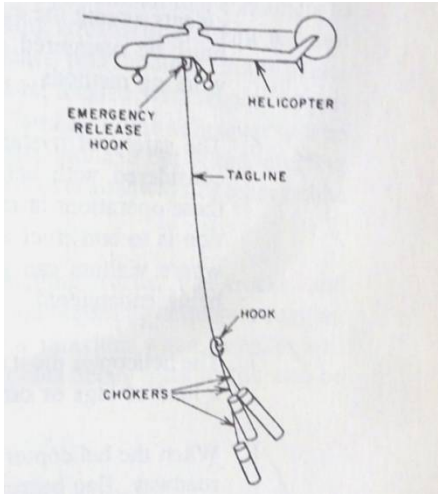
These are cable systems that use balloons filled with a lighter-than-air gas (usually helium) to provide the lifting force that fully suspends the load of logs during extraction. Cables spooled on to drums that are mounted on a winching machine are used to pull the balloon and its load to the landing and to return the balloon, with the empty chokers, to the felling site. Experience with balloon logging suggests that it is only feasible for clear-felling operations, although new developments currently being tested may change this in the future. Balloon logging also requires cutting units that are large enough to cover the high fixed costs associated with installing the balloon system at a landing. Where these conditions can be met, balloon systems cause very little soil disturbance and can reduce road construction substantially since they are capable of reaching very long distances from the landing. Because of the high initial investment and the specialized equipment and crew skills required, however, very few balloon extraction systems are currently in use.



Typical configuration of a balloon extraction system.

Helicopter extraction systems

Conceptually, these are quite similar to ground-skidding systems, except that, because the transport machines are helicopters, logs are flown from the felling site to the landing rather than being skidded along the surface of the ground. Helicopters used for logging can be grouped into three classes: those with rated lifting capacities for external loads of 2.7 tonnes or less are considered "light-lift" helicopters; those that can lift 2.7 to 5.4 tonnes are "medium-lift" helicopters; and those with greater lifting capacities (currently up to 11.3 tonnes for commercially available, non military aircraft) are "heavy-lift" machines.



Helicopter logging is accomplished by suspending below the aircraft a "tether line" (also called a tag line) of

wire rope to which chokers can be attached. In some operations a grapple hook is used rather than chokers. The tether line is typically between 30 and 100 m in length, depending upon topography and the height of any trees above which the helicopter must hover, among other factors. Long chokers are used, and these are pre-set. The ends are then brought together to make up loads that are estimated as being slightly less than the helicopter's lifting capacity.

When a load has been prepared, the helicopter flies to the hooking point, lowers the tether line to the ground and hovers while the load is attached to the tether line. Upon receipt of a signal from the loadmaster, the helicopter lifts the load above any residual trees and then flies to the landing. The logs are placed on the landing and the chokers are released by remote control from the aircraft. The helicopter then returns to the felling site for the next load of logs. A round trip between the landing and the felling site typically takes from two to five minutes.

It is widely recognized that direct operating costs for helicopter logging are many times higher than those for other types of extraction systems. Fuel costs alone are enormous - the largest heavy-lift helicopters consume nearly 2000 litres of high-octane fuel per hour! Added to this, the cost of the aircraft itself, replacement parts, and maintenance, insurance and crew salaries can make hourly expenditures for a single heavy-lift helicopter higher than those for a medium-sized sawmill. On the other hand, the great range of the helicopter, which can serve an area several kilometres in radius from the landing, makes it possible to eliminate a great deal of road construction and thereby reduce not only costs but also a major source of environmental damage.

In addition, helicopter extraction causes virtually no soil disturbance and no dam age to residual trees other than that which occurs during the cutting operation or that is associated with the landings and transport operations. For some situations, therefore, particularly where high-value timber is to be extracted, the considerable cost of helicopter logging can be justified by the combination of savings from reduced road construction and the ecological value of very low environmental impacts.

Certainly, helicopter logging is practical only in special circumstances, but where those circumstances apply it can be an attractive alternative to other extraction systems.

Recommended practices for helicopter extraction

Helicopters, especially heavy-lift machines, are capable of production rates that far exceed those associated with most other extraction systems. An aircraft that delivers 5 m^3 of logs to the landing every four minutes will produce 400 m^3 in eight hours, even allowing 20 minutes per hour for maintenance and refuelling. In good weather and with optimal flying and working conditions, helicopter operations have been reported that have produced as much as 2 000 m^3 in a day. Such high production rates put a great deal of stress on haul roads, work crews, transport vehicles and support facilities. Operations involving helicopter extraction must therefore be planned thoroughly from the very beginning, and plans must be flexible enough to adjust to rapidly changing conditions.

Typical configuration of a helicopter extraction system

- Because of the high production rates, the number of workers employed on helicopter operations is necessarily much larger than for most other logging systems. This means, for instance, that a large number of workers may be involved in cutting operations that are being carried out simultaneously over a wide area. Coordination and constant supervision are therefore especially important in order to reduce hazards while at the same time maintaining productivity at the rate needed to avoid costly delays.

- Operations must be planned so that helicopters carrying suspended loads never fly directly above workers on the ground and never follow a route that would put workers in danger from dropped or aborted loads. Helicopter crews must be made aware of the fact that workers using motorized equipment such as chainsaws may not be able to hear the helicopter approaching.

- Crews working on the ground cutting timber and pre-setting chokers are not always visible from the air, especially in partial-cutting operations. Where there is a possibility that such crews may be working near the helicopter's flight path, provision should be made for the crews to report their location to the aircrew at regular intervals or whenever necessary. Usually this is done by providing all crews with two-way radios and teaching them the protocol required for radio communication. This also has the advantage of providing a means of rapid communication in the event of an emergency. Wearing brightly coloured clothing can also help make the field workers visible to the aircrew.
-Although the safety records of helicopter logging operators are better on average than those of ground-skidding operators, serious accidents have occurred in helicopter logging, sometimes even involving multiple fatalities. Also, because of the system's high production rates, pressure to work too swiftly may increase the frequency of accidents among the cutting crews and on the landing. This tendency must be countered by a continual emphasis on safety and good working methods.

- The safety of bystanders and visitors to the logging site must be considered with helicopter logging operations since these operations inevitably attract the attention of the public. A useful precaution is to construct a viewing area some distance from the landing, where visitors can get a good overview of the operation without being endangered.

-The helicopter must never fly over areas of habitation while carrying a load of logs or some other suspended load.

-When the helicopter's flight path is likely to carry it over or near a roadway, flag bearers must be stationed along the road in positions that will permit them to prevent entry into the area of danger until after the helicopter has passed. The operation should be organized in such a way as to minimize delays and inconvenience to the public that may result from such stoppages.

- Landings where logs are to be delivered by helicopters must be of sufficient size to accommodate a large volume of logs and also to permit trucks, log loaders and workers on the landing to stay well away from the drop zone when the helicopter is delivering its load.

- Dust can be a major problem on helicopter landings during dry periods, and may interfere with the safe operation of the helicopter. A water truck may be needed to wet down the landing periodically, especially in the log-drop zone and nearby areas.

- In addition to the landing, one or more graded areas must also be prepared as landing pads for periodic refuelling and maintenance of the helicopter. Vegetation must be cleared away from these areas to permit adequate clearance by the helicopter's rotor blades during landing and take-off. Dust on the pads must be controlled, and the pads must be kept clear of objects that could be knocked loose by the down draft and fly up into the rotor blades. The refuelling pad in particular must be located sufficiently far away from the landing that it will not constitute a hazard to personnel on the landing. Fuel storage must be provided in a way that will minimize the danger of explosion and fire, and dykes must be built around fuel containers to prevent spilled fuel from contaminating streams or groundwater supplies. Where possible, the maintenance pad should be lower in elevation than the landing and, with respect to prevailing winds; its location should facilitate an emergency landing of the helicopter if required. The flight path into and out of the refuelling and maintenance pads should not pass over roadways or other public areas nor over dwellings.

- Because of the large number of logging trucks, fuel trucks and other vehicles that will enter and depart from helicopter logging areas, road signs must be placed near junctions where vehicles will enter public roads to warn the public that heavy truck traffic may be encountered.

1.3. MAJOR TRANSPORTATION

1.3.1 Loading devices

Front end loaders usually have forks or grapples and are mounted on crawlers tractor or articulated four wheel drive tractor. In semi mechanized loading logs may be lifted or rolled up the loading skids by cables and different kinds of tractors and winches. Semi mechanized loading often requires workers to be on the ground attaching the releasing cables, guiding the load and so on, often using hoops, livers and other hand tools.

1.3.2. Surface transportation

Road transport of timber is carried out by vehicles the size of which depends on the dimensions of the timber, road conditions and traffic regulations, and the availability of capital to purchase or lease the equipment. Two or three axle trucks with carrying capacity of 5 to 6 tonnes are commonly used in tropical countries

1.3.3. WATER TRANSPORTATION

Transportaion through water.

In areas where forests are inundated with seasonal rains, as in parts of the Amazon basin, or located in tidal or mangrove areas, water can be used to extract logs from felling

sites. Normally, cutting is done during the dry season or at low tide, and the logs are floated out as the water rises. Loss of logs can be high with such systems, so careful control is needed to avoid wasting a large part of the resource. For dense timbers, felling must be done well in advance so that the logs have enough time to dry out and float better as a result. In tidal areas, the trees may need to be killed in advance of the operation, usually by girdling, and then left to dry out for a period before cutting and extraction. Especially dense logs may need to be tied securely on to rafts of more buoyant logs to prevent them from sinking. Environmental impacts with water-extraction systems include those associated with direct felling damage as well as eventual accumulation of bark, scattered residues on the river banks or woody debris in the waterways. Where tidal flushing occurs or streams are flowing quickly, this accumulation should not pose problems. The decay of bark and woody debris removes free oxygen from the water, however, and this can adversely affect aquatic life, especially in slow-moving streams. Perhaps more significant are environmental problems associated with the extensive cutting of non-commercial trees for use as floaters in rafts. One estimate is that for each commercial tree extracted, another tree was also felled. Soil damage along stream banks also occurs frequently when the logs slide or are rolled into the stream.

Water transport of logs.

- Log rafts should be securely bound in order to prevent the loss of logs and to ensure the safety of other traffic using the waterway. Flags and lights for night travel should be used to identify the front and rear points of the raft clearly in order to avoid collisions. Large rafts should be towed or pushed by boats with sufficient power to control safely the speed and direction of the raft.

- To ensure the maximum utilization of harvested timber, logs should be individually branded and tallied in the forest, and the brands and tally sheets should be checked at the landing as well as at the delivery point.

1.4. Logging planning

Planning of timber harvests is one part of overall forest management planning, which is itself a component of comprehensive land-use planning.

Harvest plans are of two types: strategic and tactical. The strategic harvest plan, prepared by the forest planning team, is a long-term plan that answers the following questions for the forest or concession area as a whole:
- what type of harvesting must be done;
- why it must be done;
- where it must be done;
- when it should be done.

The strategic harvest plan should demarcate non-harvest areas, divide the harvestable forest into annual operating areas (coupes) and design the main transportation system.
The tactical harvest plan, prepared by the team directly responsible for supervision of harvesting operations, is a short-term plan that answers the following questions for each coupe:
- how the harvesting is to be done, in detail;
- who will carry out the operations;
- when each part of the coupe should be harvested.

Guiding principles

Forest harvesting operations are most likely to meet economic, silvicultural, environmental and social objectives if they are carried out as outlined in a properly prepared harvest plan.

Before harvest planning is initiated, a comprehensive land-use plan should be completed to identify the permanent forest estate and the portions of this estate on which timber harvesting will be permitted. Areas where forest plantations will be established should be identified and quantified. The land-use plan should also show areas of forest, if any, from which the trees are to be removed so that the land can be used for other purposes such as agriculture. Commercial timber harvesting is normally permitted in these areas of conversion forest, but it must be recognized that such harvesting is inherently unsustainable. This model code of practice does not explicitly consider harvesting in conversion forests, although practices similar to those recommended in these guidelines would be appropriate in such situations in order to best preserve the environment during the conversion process.

An essential requirement for strategic harvest planning is the development of a comprehensive forest management plan. It is important to remember that harvest planning by itself is not forest planning; the harvest plan is only one part of a complete forest management plan. It is unquestionably an important part, however, since harvesting generates revenues and provides an opportunity to modify the forest so that it can contribute most effectively to economic, social and environmental objectives. But harvest planning cannot be done in isolation from forest planning; the two are complementary and should be undertaken

simultaneously by an interdisciplinary planning team that includes foresters, ecologists, logging specialists, engineers, wildlife biologists and other individuals representing specialities in the social sciences.

Comprehensive harvest planning is essential in order to set the stage properly to enable sustainable harvesting practices to be followed, and also to reconcile the need for greater technical control during harvesting with the need to reduce harvesting costs simultaneously. Many logging operators believe that environmental protection can only be achieved through costly measures that will drive them to the brink of bankruptcy. This is simply not true. The experience of operators who develop thorough harvest plans and then carry out the operations as specified in these plans has demonstrated clearly that these procedures not only improve operational control and reduce environmental impacts, but can also reduce costs and substantially increase profits.

Objectives

Strategic and tactical harvest plans should specify ways of:
- optimizing harvesting production rates;
- minimizing environmental and other impacts associated with harvesting operations;
- accommodating the needs and wishes of local communities and indigenous peoples and making provisions for their participation in making decisions about harvesting operations and in benefiting financially and economically from those operations;
- providing efficient access to the forest for silvicultural, protection and transport purposes;
- minimizing harvesting and transport costs, subject to constraints imposed by environmental, ecological and social considerations;
- identifying opportunities to coordinate timber harvesting with the collection of non-timber forest products;
- avoiding scheduling problems;
- providing for flexibility so that the plans can be changed to take advantage of new information or changing situations;
- protecting the health and safety of workers and the public.

Potential consequences of inadequate planning

Far too many harvesting operations are carried out without the benefit of any kind of formal, written plan. Such operations are difficult to coordinate, impossible to control adequately and in their effects often more closely resemble mining operations than harvesting operations designed for the sustainable utilization of forest products.

Even where harvest plans are required, often only a tactical plan is prepared. This means that the transportation system is developed in a piecemeal way, with roads being planned separately for each coupe rather than a system being designed for the entire forest with roads being constructed when access to an individual coupe is required. Consequently, far more forest area than is necessary is cleared to build roads, resulting in accelerated soil erosion, increased stream sedimentation and higher costs of road construction, maintenance and transportation.

Lack of adequate harvest plans may also result in scheduling problems that greatly increase disruptions and force logging supervisors to manage from crisis to crisis rather than being able to carry out operations in a systematic, organized way.

Recommended practices

Strategic planning

Tactical planning

Strategic planning

This type of harvest planning cannot be separated from management planning, as both must be done simultaneously by an interdisciplinary planning team.

A map and a written plan are elements of a good strategic harvest plan. The map, typically drawn to a scale between 1:10 000 and 1:50000, should show the following features as identified in the forest management plan:

- forest cover types, important topographic features (preferably with elevation contour lines),
- streams and both existing and planned infrastructure or other artificial features;
- protection areas such as biological reserves, religious or cultural sites or areas near population centres;
- areas where harvesting is to be carried out, divided into annual coupes or similar areas that can be conveniently referenced on the ground;

- areas where major problems exist that must be overcome when developing the transportation system or in carrying out the harvesting operations. These would include rock outcrops, swamps or other areas of wet soils, important stream crossings and other features;
- areas of non-forest land uses;
- locations of communities or indigenous populations that could be affected by harvesting or transport operations.
- The written plan should describe in detail the items shown on the map. This plan would typically include the following:
- a description of the planned silvicultural treatment (e.g. individual-tree and group selection, shelterwood and clear-felling) for each harvesting coupe and an explanation as to why each treatment has been selected, including an analysis of the degree to which harvesting is expected to contribute to the attainment of management objectives for the forest;
- a description of the types of harvesting equipment to be used in each coupe (for example, 20 percent of the area to be extracted with cable systems, 60 percent with rubber-tyred skidders, 5 percent with draught animals and 15 percent with helicopters), with an explanation of the selection criteria employed;

- an estimate, based on a proper inventory, of the volume of timber to be removed from each coupe, preferably divided into species or groups of similar species;
- a schedule showing the year in which each coupe is to be harvested;
- descriptions of any special problem areas noted on the map, with suggestions for overcoming the problems;
- a discussion of potential problems relating to local communities or indigenous populations and the way these problems have been addressed in formulating the plan;
- detailed information concerning the forest transportation system, such as road design parameters for different conditions (valley bottoms, ridgetops and climbing roads), locations and specifications for major stream crossings, typical spacing and design specifications for drainage structures and other similar information;
- annual labour requirements for harvesting operations and for construction and maintenance of the forest transportation system;
- provisions for living quarters and other facilities needed to accommodate forest workers, together with general information on health and safety provisions;
- the estimated cost of harvesting operations in each coupe and of construction and annual maintenance of the forest transportation system.

Tactical planning

Short-term tactical plans normally provide details of operations that are to be carried out during a period of one year or some other convenient unit of time, such as a dry season. Thus, a tactical plan is associated with the annual coupe. Sometimes, however, a coupe is not a single, contiguous block, but instead the areas to be harvested within a year are dispersed throughout several separate regions of the forest. The nature of the coupe largely depends upon the type of forest, its stage of maturity and the administrative preferences of the agency responsible for forest management.

The tactical plan, like the strategic plan, should include a written description of the planned operations as well as a detailed, accurately scaled map. The plan should be consistent with environmentally sound harvesting practices such as those recommended in Chapters 3 to 7 of this model code of practice. The following steps are recommended for the development of tactical harvest plans:

A topographic survey should be conducted, either on the ground or by using low-altitude aerial photography with ground checking, and a large-scale topographic map prepared. The best maps for detailed harvest planning are usually drawn at scales between 1:2 000 and 1:10 000, depending upon the topographical irregularities and the types of harvesting equipment to be used. In some areas, maps with scales as small as 1:20 000 are used for tactical harvest planning, but this scale provides less detail than is desirable for satisfactory planning.

The contour interval selected for the topographic map will depend upon the topographical irregularities and the relationship between the costs of mapping and those of harvest planning errors. In general, additional money spent on preparing good maps will pay off in reduced harvesting and infrastructure costs. A contour interval of 5 m or less usually

provides satisfactory detail for planning, as long as the contour lines accurately represent the ground surface.

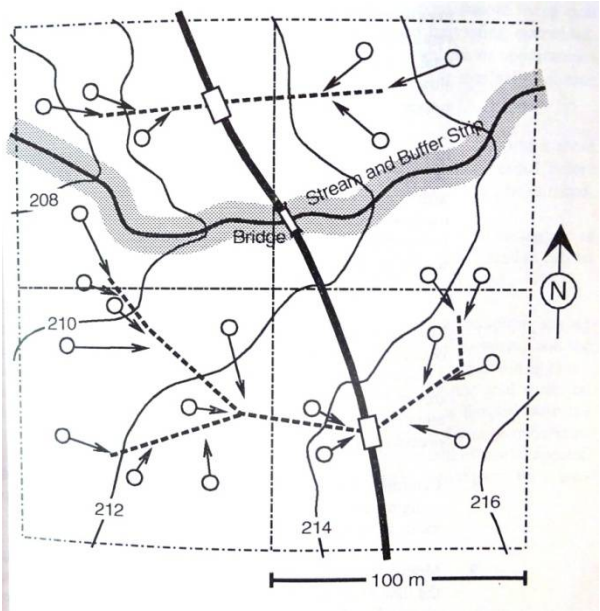
The topographic map should accurately show the boundaries of the harvest area and the location of water courses, swamps or other areas of wet soils, gullies, rock outcrops, sites of religious or cultural significance and any other feature that may influence harvest planning.

The annual coupe should be divided into administrative units that can be identified on the ground and used to help control and guide the operation. If these units, referred to here as "cutting units", are contiguous, then planning should be done for all of the units simultaneously. If they are dispersed, then individual plans may need to be developed for each cutting unit or group of cutting units.

An individual cutting unit should be limited to a single extraction method. This is because the planning of harvesting operations for cable systems is significantly different from that for ground-skidding machines or forwarders, and different again from that for skidding with draught animals or extraction with aerial systems such as helicopters. For administrative purposes, operations that use different extraction methods should therefore be allocated to different cutting units.

On the topographic map, streamside buffer zones should be delineated as well as other special management areas in which cutting is either to be prohibited altogether or will be subject to special restrictions. These might include areas of significant scientific, recreational, cultural or aesthetic value, special reserves for wildlife or for the production of non-timber forest products, water catchments, areas of saturated soils and erosion-prone sites.

Using the topographic map as a guide, an inventory of the trees in the operating area should be conducted to estimate the timber volume and its distribution over the cutting unit, as well as the number and condition of potential crop trees that are currently immature and should be protected to form a future crop. The kind of inventory needed for this purpose will depend upon the type of forest and the cost of carrying out the inventory. In temperate forests, a sampling inventory is usually sufficient, as the volume to be harvested from each hectare is relatively high and the trees are reasonably uniform in size; it is not necessary for planning purposes to know the location of each individual tree to be harvested. In the mixed broad-leaved forests of the tropics, the volume harvested per hectare is typically quite low, although the value of an individual tree can be substantial. In such forests it is now generally considered essential to make a complete inventory of all trees that might be harvestable. Each tree should be identified and numbered, its diameter should be measured and the commercial stem quality assessed. If standard volume equations are used, the tree's height should also be measured. These data should be recorded on inventory sheets and the tree's location should be marked accurately on the topographic map.



Part of 1:5000 tactical planning map for a harvesting operation in a tropical forest. The circles indicate trees to be felled, and

the arrows show the planned felling direction. Heavy dashed lines represent skid trails, and the two open rectangles are landings. Such a map can be taken into the field when marking trees for felling and laying out skid trails, and later it can also be used by the felling and extraction crews. After the operation has been completed, the map will be useful in post-harvest assessment to compare the actual layout with that specified in the harvest plan.

The inventory data for the operating area should be tallied, and, for selection harvesting, the trees to be harvested must be determined. This will depend on such considerations as management goals, market acceptance, diameter limits, silvicultural guidelines, operating constraints and estimated harvesting cost.

A detailed transportation and extraction system for the operation should be laid out, using the topographical map, with those trees to be harvested marked on it. Such a plan will include the haul roads that will connect to the main transportation system, the landings where logs will be concentrated during the extraction process and the skid trails (if ground-skidding systems are to be used) or cableways (if cable systems are to be used). This system must be laid out so that it efficiently accesses the trees to be harvested while accommodating the terrain, circumventing problem areas, avoiding streams and minimizing the total length of roads and skid trails. Where a stream cannot be avoided altogether, the site should be surveyed in the field and a stream crossing designed that will minimize environmental problems.

In steep terrain, it is often desirable to first locate potential landing sites and then see whether or not it is possible to reach them with roads. The full transportation system, including both roads and landings, thus becomes a matter of compromise between the optimal locations for landings and the reality of where it is environmentally, economically and physically possible to build roads.

In tropical forests or other areas where planning involves decisions about individual trees, the approximate direction of fall for each tree to be harvested should be determined using the transportation plan as a guide. This direction should be marked on the map; it is to be verified in the field and changed if necessary when the tree is actually marked for felling'

Specific harvesting equipment to be used should be determined and a preliminary operations schedule developed, using appropriate estimated production rates.

The preliminary schedule must be modified as necessary to accommodate the timing of the normal onset of the rainy season. Contingency plans should be developed for severe storms and other extreme events. The time of seed fall must also be considered in areas where seed is not produced year-round, such as in many deciduous and semi-deciduous forests.

Whether harvesting operations on some cutting units need to be scheduled to avoid breeding seasons of primates or other sensitive animals or the nesting seasons of rare or endangered bird species that may be present in the area needs to be determined.

The possible complementarily of harvesting non-timber forest products should be considered (for example, cutting rattan or tapping resins prior to the timber harvest or collecting fuelwood after the harvest). If appropriate, these products should be included in the harvest plan.

Local communities or indigenous peoples living near the harvesting site should be consulted about the planned harvesting operations, including any potential scheduling problems or opportunities (for instance, ready labour availability during slack agricultural periods).

Relevant landowners or government authorities should be contacted about any right-of-way easements that might be needed before road building or other construction activities can be initiated.

Before finalizing the harvesting plan, loggers should be consulted to ensure that the plan is feasible and that the operation can be undertaken safely, efficiently and economically.

Copies of the harvesting plan and the accompanying topographic map showing the trees to be harvested and the transportation system must be given to the supervisor of the harvesting crew, who will be responsible for ensuring that the plan is carried out and that every member of the crew is familiar with the requirements and working procedures. A thorough understanding of what is to be done and the standard of work expected is perhaps the single most important requirement for a successful operation.

1.5 TIMBER DEPOT MANAGEMENT

Depot

A depot is a place where wood or other forest produce is stored pending its disposal. The depots may be (1) forest depots, (2) transit depots, and (3) sale depots or permanent depots. Forest depots are temporary and formed for assembling and checking the produce before despatch from forest. Transit depots are intermediate depots inside or outside forest where the forest produce is temporarily stored pending its movement to destination. A forest depot may be called a transit depot. The purpose of transit depot is also collection of produce and checking before further movement.

Sale depot or permanent depot

These are the depots where forest produce is stored pending its disposal by sale. These depots are of permanent nature because produce stays in these depots for relatively longer time, and the depots are used for produce of a number of coupes over the years

(i) Location

Location and layout should be well planned. The location should be such that (i) it is not far off from the present and prospective coupes of near future so that extraction cost and

time remain within reasonable limits, and (ii) it is well connected by metalled roads so that the buyers find it easy to transport produce from the depots.

(ii)Typical Layout of a Stores Depot

The depots should be constructed over a site of relatively high level, which is not waterlogged and not prone to land slip or soil erosion. The depot area should be enough to accommodate produce of a number of coupes. The area should be divided into a number of plots or sections, serially numbered, allotted to produce of different coupes. The various plots/sections should be separated by a network of roads so that trucks or carts may ply along, and load or unload coupe produce with ease. For each plot there should be a signboard displaying the coupe name and the contents.

Stacking – Following points are in general worth considering.

For the convenience of management and control of inventory, produce of different coupes should be stored in separate plots/sections. Within a plot(s), produce of a coupe should be separated species wise and then product wise, i.e. logs, poles, firewood etc.

Before forming final stacks, material of the same product of a species is further separated in terms of size and quality. For example, logs of Sal coming from the same coupe are differentiated in terms of girth and length class and to the extent possible, inferior and defective logs are separated from the sound ones. In a word, a stack should contain produce of comparable size and quality.

The stacks should be as close as possible, subject to inspection facility, to economise space. The logs and poles may be stacked in multiple layers with space between the individual pieces so as to permit measurement and inspection. Preferably, the lowest tier of logs should be kept off the ground by skids which can be round or square pieces. The firewood should be piled in stacks as compact as possible.

Formation of Lots - After a coupe produce has been differentiated and stacked species wise, product wise, size and quality wise, in that order, lots are formed, which consist of one or more stacks of a particular product. To each lot a unique lot number is assigned; the number generally contains both numerical figures and words indicating some serial number, the coupe, year of extraction etc. For each lot, a marking list is prepared, which contains lot number and details of the produce forming the lot. Lots should be formed as early as possible. Lot formation should start as soon as a depot receives reasonable quantity of produce that permits grading of a product.

Lot size depends on (1) expected price of the lot vis-a-vis buying power of the merchants and 2) carrying capacity or full load capacity of the carriage (truck, tractor, cart etc.) prevalent in the locality.

Depot Register/Forms

For incoming produce , name of the coupe, date of receipt, description of produce including measurement received date wise, depot serial number assigned for logs, plot or section number where stacked etc.

For outgoing produce – Lot reference, order of the competent authority, sale price, if applicable, buyer/recipient of produce, date of lifting, Transit Pass reference etc.

It is important to note that any record for influx or out flux of produce is done chronologically that is in the order of time they occur.

Model forms which is being maintained in the forest timber depot where timber were harvested from canal bank Teak plantations in Thanjavur Forest Division are given below.

Form – I

It is a register of yield of material in each block or plantation maintained in the Range office of the concerned depot. Periodic return of Form-I will be sent to the concerned District Forest Officer by the Ranger.

TAMILNADU FOREST DEPARTMENT

THANJAVUR FOREST CIRCLE, THANJAVUR FOREST DIVISION.

CENTRAL TIMBER SALE DEPOT RANGE, PILLAIYARPATTI

(Code section 34 and 87)

FORM No.1

REGISTER OF ANNUAL YIELD IN MATERIAL OF THE ..... BLOCK..... RANGE.....DIVISION.

Month	Block or compartment.	Description of forests.	Nature of cutting.	Description of trees or other produce.	Number of trees giving.	TIMBER				Poles.	Firewood and Charcoal.	Bam boos.	Sandal wood.		Grazing and fodder grass.	Grass and other minor produce.	Remarks
						Logs		Scantlings.									
						No.	M^3	No.	M^3	No.	Number of tonnes or Kg. or M^3	No.	Tonnes.	Kgs.	Rs.	Rs.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Note:- If the number of trees cannot be given as happens in the case of coppice fellings,or if dry and fallen wood is cut,column (6) may be left blank and the entry made in columns (7) to (12) only.

Form –II

Form –II should be recorded before felling starts. Bio metric measurements for matured standing trees, dead trees, wind fallen trees will be taken as per norms using appropriate height measuring instruments and recorded in this form.

TAMILNADU FOREST DEPARTMENT

THANJAVUR FOREST CIRCLE

THANJAVUR FOREST DIVISION.

FORM - II

(Trees Marked before Felling) Section (45 & 49

Division :

Range :

Name of the Plantation - :

Section :

Starting place - :

End place - :

ABSTRACT					
LB/ RB	TEAK	SISSOO	EH	TA	TOTA
LB					
RB					
TOTAL					

GPS Readings		
Starting place	Mid Place	End Place

OFFICER'S INSPECTION DATES			
FRO	DFO	CCF	REMARKS

Name of the Depot :

Plantation place Starting to End Average Distance KM :

Plantation Starting Place to Depot Distance KM :

Estmated total Distance :

Sl No.,	Mile stone / Land Mark	Tree No.,	Species	Estimated Height/ Length	Bottom Girth	B / H Girth	Estimated Length of Valid Branches				Total Length	Remarks
							A	B	C	D		
				Mts.	Mts.	Mts.	Mts.	Mts.	Mts.	Mts.	Mts.	

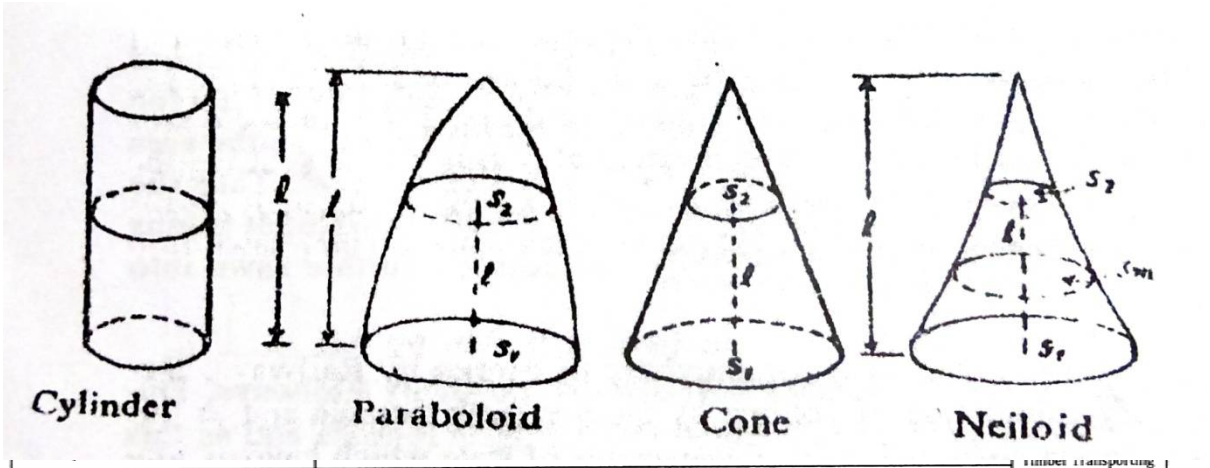
RB - Right side of the bank LB – Left side of the bank

1983 Ottangadu, Canal Bank Teak plantation at Pattukkottai Range, Thanjavur Dividion. Tamil Nadu. Marked for felling.

Form-III

After the enumerated trees are felled using the right felling technique they are converted carefully and economically. Length, middle girth (under bark), top girth and bottom girth of each converted log should be taken and recorded which will be helpful to identify the missing log and tree forms. The measurements recorded in form -II and in Form-III should coincide approximately and tree forms are compared. Branches are labelled in Alpha bet seriel like A,B,C,D ..etc and the billets like A1,A2..etc.

Volume of various solids and their frustrums



Form II						Form III									Timber Transporting Details	
Sl.No.,	Tree No.	Species	Length(mts)	Bottom Girth (mts)	BH Girth (mts)	Sl.no.,	Log No.	Length(mts)	Bottom Girth (mts)	Mid Girth Under Bark (mts)	Top Girth (mts)	Volume(m^3)	Class	Remarks	Invoice No.	Date

Volume of logs

Logs.S. No.	Form of solid	Volume of Full solid	Volume of Frustrum	Remarks
1	Cylinder	SL	SL	
2	Paraboloid	SL/2	$\frac{(s1+s2) * L}{2}$ Sm * L	Smalian's formula Huber's formula

3	Cone	SL/3	$\frac{(S1+S2+\sqrt{S_1 S_2}) * L}{3}$	
4	Neiloid	SL/4	$\frac{(S1+4Sm+S2) * L}{6}$	Prisoidal or Newton's Formula

S - Sectional area at the base in square unit

S1- Sectional area at thicker end in square unit

S2 – Sectional area at Thinner end in square unit

Sm - Sectional area at the middle in square unit

L - Length of the log in linear unit

Quarter girth formula to determine volume of log.

$$\text{Volume} = L * \left[\frac{Gm}{4}\right]^2$$

G = Girth at mid point

L = Length of the log

Form –IV

Form –IV register is maintained in forest depot comprising details of disposal of timber from felling site. Fallowing details are entered in the register.1.Number of bill or pass.2. Date, 3. Details of disposing materials, 4. Description of the produce, 5. Depot No. Of the log.6. Marks. 7. Number or quantity.

Timber in Transit.

When the timber is transported from a Government land to another Government land i.e. from forest depot to sale depot Farm I Black permit is used which contains 1.Invoice No.2.Date of dispatch. 3 Means of transport and destination. 4. Name of the Sepcies. 5. No. Of logs. 6. Dimensions of the log etc.

Form I

[Referred to in rules 3 (1), 4(a) and 5 (e).]

Invoice and permit for timber removed

from.....to .....

No.

1.Name and residence of person to whom permit is granted.

2.Marks on timber :

3.Route :

4.Time allowed :

Log No.,	Species.	Length	Girth			Volume	Remarks
			Bottom	Mid	Top		

Signature of the Range officer

Acknowledgement

Log No.,	Species.	Length	Girth			Volume	Remarks
			Bottom	Mid	Top		

Signature of the Receiving officer

Depot Log Receiving Register

When the log reached the Depot the invoice should be carefully examined and the measurements of the logs are verified. If there is any variation it must be corrected and acknowledged back to the sender. The following details are entered in the Log receiving register.1.S. No.2. Invoice No. And date.3. Name of the plantation , Range , Section.4. River ID with Bank..5. Log No. 6. Depot Log receiving No. 7. Length. 8. Girth (Bottom, Mid, and Top) 9. Volume. 10. Class. 11. Utilized Lot No. 12. Remarks.

Monthly abstract of the Depot receiving register with details of Logs, Class and Volume will be helpful to fill up Form – V

If any wood related to offence is received Offence Report No. Should be recorded in the Depot Register and also details of logs utilised in Lot register.

Timber classification.

Timbers are classified in to three major classes according to soundness and defects.

A Class – Straight and without any defects.

B Class – Logs with fallowing defect are classified as B Class.

Knots - Knots not exceeding three in number and size of the knots less than 10 cm in diameter

Splits – Single split at one end with less than 50 cm in length

Buttressing – If the mid girth is not less than 2/3 of the butt end.

Tappering – If the mid girth is not less than 15% of girth at butt end.

C Class – Logs having more than one and above specification are classified as C Class.

Other classification of the logs in the sale depot is as fallows

Tamilnadu Forest Department
Thanjavur Forest Circle, Thanjavur Forest Division.
Pillaiyarpatti Central Timber Sale Depot.
Timber Classification Table for Teak & Sissoo Logs

No.,	Class	Length in Mts	Girth in Mts	Girth taken at the	Remarks
1	AL I	6 M and above	1.50 M and above	Middle	Logs straight and sound without any defects
2	AL II	6 M and above	1.20 M to 1.49 M	Middle	
3	AL III	6 M and above	0.90 M to 1.19 M	Middle	
4	A I	Below 6 M but not less than 2.5 M	1.50 M and above	Middle	
5	A II	Below 6 M but not less than 2.5 M	1.20 M to 1.49 M	Middle	
6	A III	Below 6 M but not less than 2.5 M	0.90 M to 1.19 M	Middle	
7	B I	2.5 M to 5.99 M	1.50 M and above	Middle	Fairly straight and sound logs
8	B II	2.5 M to 5.99 M	1.20 M to 1.49 M	Middle	
9	B III	2.5 M to 5.99 M	0.90 M to 1.19 M	Middle	
10	C I	2.5 M to 5.99 M	1.50 M and above	Middle	Defective and crooked logs
11	C II	2.5 M to 5.99 M	1.20 M to 1.49 M	Middle	
12	C III	2.5 M to 5.99 M	0.90 M to 1.19 M	Middle	
13	SL I	Below 2.50 M but not less than 1.50 M	0.90 M and above	Middle	Short length
14	SL II	Below 1.50 M but not less than 1.00 M	0.90 M and above	Middle	
15	UC I	Logs having not less than 1.00 M	60 cm to 89 cm	Middle	Unclassified
16	UC II	Logs having not less than 1.00 M	30 cm to 59 cm	Middle	
17	TPL I	9 M and above	0.75 M to 0.89 M	Bottom	Teak Pole Long
18	TPL II	9 M and above	0.60 M to 0.74 M	Bottom	
19	TPL III	9 M and above	0.45 M to 0.59 M	Bottom	
20	TPL IV	9 M and above	0.30 M to 0.44 M	Bottom	
21	TPM I	6 M to 8.99 M	0.75 M to 0.89 M	Bottom	Teak Pole Medium
22	TPM II	6 M to 8.99 M	0.60 M to 0.74 M	Bottom	
23	TPM III	6 M to 8.99 M	0.45 M to 0.59 M	Bottom	
24	TPM IV	6 M to 8.99 M	0.30 M to 0.44 M	Bottom	
25	TPS I	3 M to 5.99 M	0.75 M to 0.89 M	Bottom	Teak Pole Short
26	TPS II	3 M to 5.99 M	0.60 M to 0.74 M	Bottom	
27	TPS III	3 M to 5.99 M	0.45 M to 0.59 M	Bottom	
28	TPS IV	3 M to 5.99 M	0.30 M to 0.44 M	Bottom	
29	TP US	1 M to 2.99 M	0.30 M to 0.89 M	Bottom	Under Size
30	CL I	2.5 M and above	1.25 M and above	Middle	Sissoo
31	CL II	2.5 M and above	Below 1.25 M	Middle	
32	SL	1 M to 2.40 M	0.60 M and above	Middle	

Form V.

Receipt and disposal of the timber and the balance available at the site will be entered in Form V register.

TAMILNADU FOREST DEPARTMENT
THANJAVUR FOREST CIRCLE
THANJAVUR FOREST DIVISION.
CENTRAL TIMBER SALE DEPOT RANGE. PILLAIYARPATTI
FORM - V

RECEIPTS AND ISSUES OF TIMBER AND OTHER PRODUCE IN DEPOTS, DURING THE MONTH OF .....

Form No : 5

Code Section -45,49,51,52,53,59,and 149

Serial number	Name of the depot	Description of timber and other produce	On hand ..... Number or quantity			Received during the month	Number or quantity			Total Number or quantity			Disposed of during the month	Number or quantity			Balance On..... Number or quantity			Remarks
			No.of Lots	No.of Logs	Cubic Metre or other unit	Whence received	No.of Lots	No.of Logs	Cubic Metre or other unit	No.of Lots	No.of Logs	Cubic Metre or other unit	How disposed of	No.of Lots	No.of Logs	Cubic Metre or other unit	No.of Lots	No.of Logs	Cubic Metre or other unit	
1	2	3	4		5	6	7		8	9		10	11	12		13	14		15	16

Monthly return of Form V extract received from forester will be consolidated and submitted to the Didtrict Forest officer.

Lot Register

After timbers are classified into various classes they are grouped into Lots according to the prevailing market scenario and a register is maintained with fallowing details.
1. S. No, 2. Lot No, 3. Class, 4. No. Of logs, 5. Volume, 6. Depot No.7. Log No, 8. Length, 9.Girth (Bottom, Middle, and Top of the log), 10. Remarks.

Model entry is as fallows

TAMILNADU FOREST DEPARTMENT

THANJAVUR FOREST CIRCLE

THANJAVUR FOREST DIVISION.

CENTRAL TIMBER SALE DEPOT RANGE. PILLAIYARPATTI

LOT REGISTER

2015-16

SL. NO	Lot No.	Class	No.of Logs	Total Volume (M^3)	SL NO	Depot No.	Log No.		MEASUREMENTS Length (mtr)	MEASUREMENTS Mid Girth	Volume (M^3)	Remarks
1	4	SL-I	6	0.981	1	581	51	B	2.20	1.10	0.166	
					2	557	191	A	2.40	1.30	0.254	
					3	576	199	A	2.45	1.11	0.189	
					4	82	2		2.30	0.95	0.130	
					5	566	194	A	1.55	0.97	0.091	
					6	586	54	C	2.00	1.10	0.151	
											0.981	

f

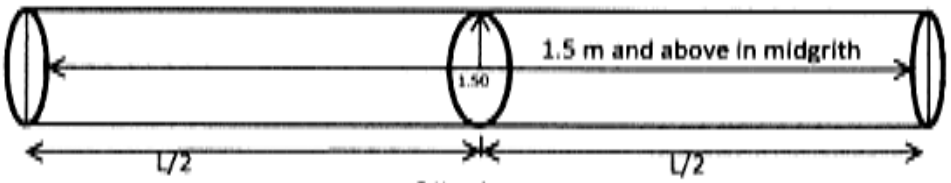
Formation of lots in the sale depot

Lots kept for sale

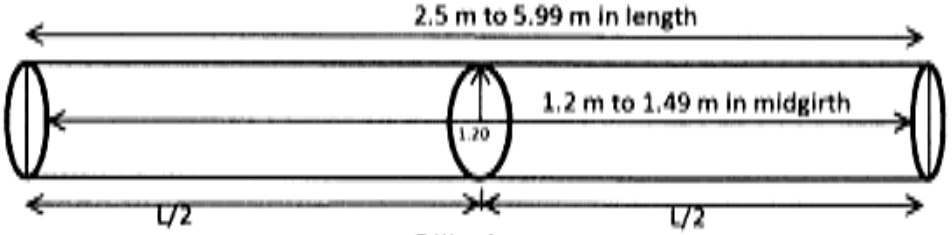
Stacks of lots with sufficient aisle space for movement of vehicles

Teak Classification Diagram :-

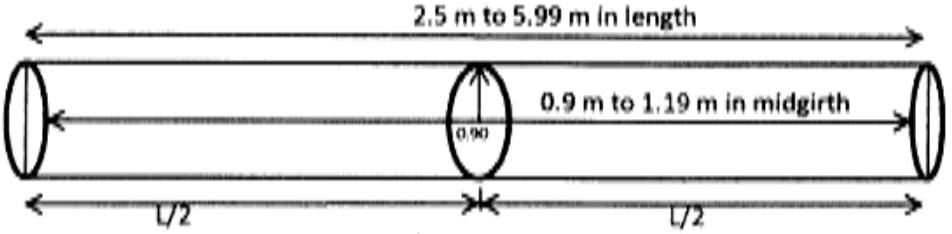
C I - class
2.5 m to 5.99 m in length



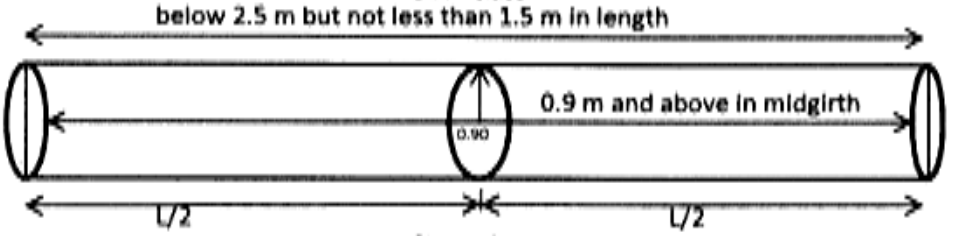
C II - class
2.5 m to 5.99 m in length



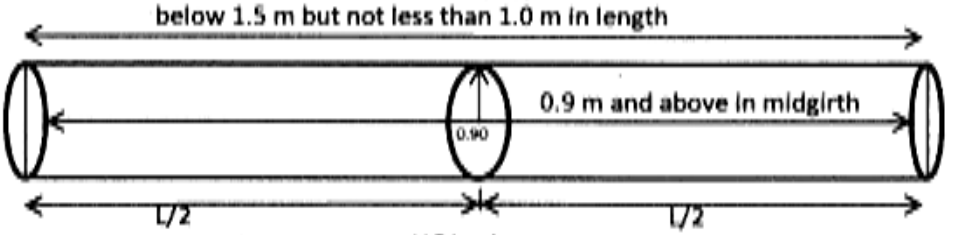
C III - class
2.5 m to 5.99 m in length



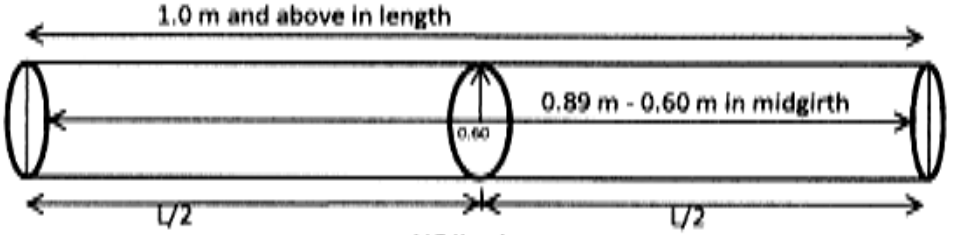
SL I - class
below 2.5 m but not less than 1.5 m in length



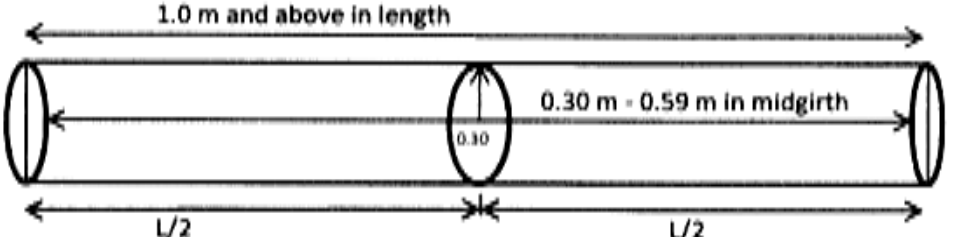
SL II - class
below 1.5 m but not less than 1.0 m in length



UC I - class
1.0 m and above in length



UC II - class
1.0 m and above in length



UC III- Class

Protection

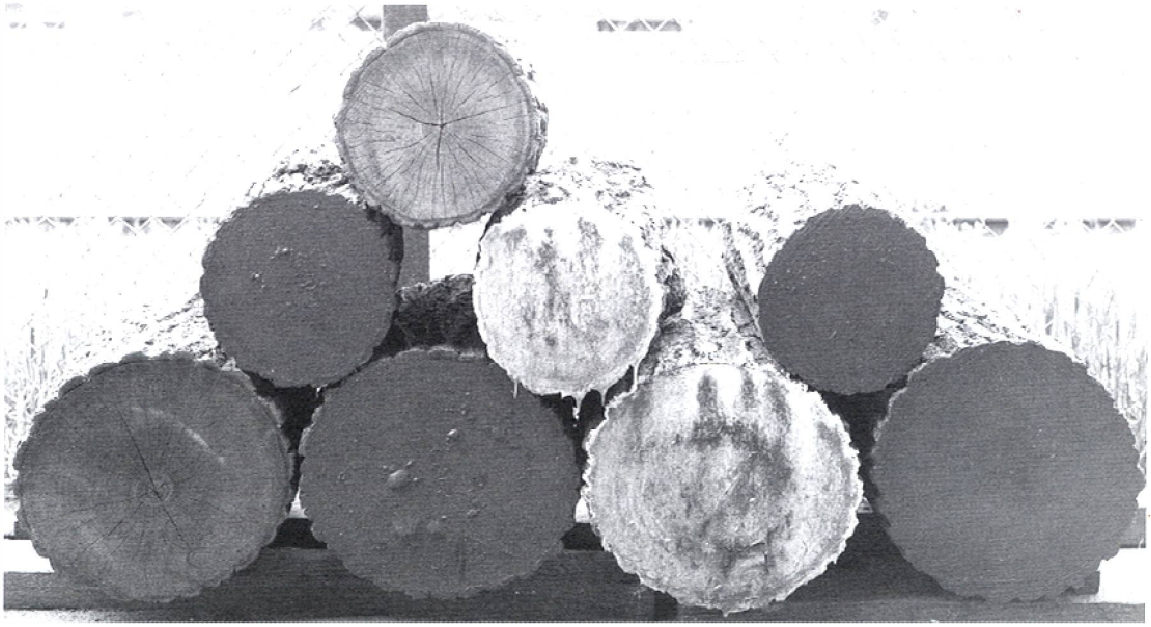
The two most important factors against which protection of depot is absolutely essential are fire and theft. Depots should be fenced with barbed wire. Every permanent depot should have arrangement for round-the-clock watch and ward. Big depots should be provided with watch tower located suitably in the depot so as to command good view of the entire depot area. Besides, there should be arrangement of electric lights for good visibility at night. The depot area should be kept clean from weeds and grasses, particularly in dry season. On the outside around the depot, a clear strip free from grass and shrubs may be maintained by occasional controlled burning. The depots should have provisions of fire fighting material like water, sand and fire extinguisher.

Post harvest operation

After felling, the main stem of the tree is detached from the crown, except when transpiration drying is desired. The main stem of the felled tree is either left full-length (tree-length log) or cut into shorter logs with lengths that correspond to lengths of the in-tended lumber. Tree-length and standard-length logs should be sawn into lumber as soon as possible after felling, especially during warm weather. However, prompt sawing of logs is not always possible because of log transportation difficulties or the economic need to stockpile logs at the saw mill. This section suggests methods for reducing drying defects that result from prolonged storage of logs. Logs need to be stored under conditions that will min-imize defects associated with shrinkage, mainly end checking, and attacks by fungi, bacteria, and insects. Defects associated with shrinkage are minimal during periods of cloudy, wet weather and low temperatures. Fungi and insects are inactive at temperatures below 32 °F or under conditions of wet storage with low levels of oxygen. On the other hand, many types of bacteria can grow in wood under wet, anaerobic conditions, but not at subfreezing temperatures. There are two general methods for storing logs: dry storage and wet storage. Precautions must be taken with each storage method to ensure defect-free lumber.

Logs With Bark

Most lumber that needs to be kiln dried will be sawn from logs that were stored on land with the bark intact. If the logs do not contain wet wood, then any lumber drying problems will usually be associated with serious end checking of the logs, insect attack, and sapwood stains. End checks can occur in all species of logs and are more pronounced in the denser hardwoods. Deep end splits can sometimes occur in the log ends, but these are the result of residual tree growth stresses that be-come unbalanced after the log is bucked, and they can-not be prevented by measures for reducing end checking. End checks are minimized by keeping the log ends in cool, moist, and shaded locations. If the logs are valuable and cannot be sawn into lumber within a short time, then the ends should be coated with a suitable end-sealing compound. The end coating should be thick enough to cover all wood pores, cracks, and irregularities on the surface, yet viscous enough so that it neither cracks nor “sags “excessively. It is good practice to treat the log ends with chemical fungicide before end coating to prevent sapwood staining.



logs 8 months after they were cut and the ends treated with preservatives. All but two logs were also end sealed; no end checking developed in these logs. The preservative treatment of the unsealed logs (topmost and lower left) was of little value once the barrier of the surface-treated wood was ruptured by seasoning checks.

Logs with heavy sapwood stain at the ends.

Fungal blue stain will develop in the sapwood of exposed log ends and debarked surfaces during warm weather within 2 weeks after the tree is felled .Applying or spraying chemical fungicides on all exposed log surfaces will provide adequate protection if the wood

does not check or split. These chemically treated areas should then be coated with a log end-sealing compound to prevent checking and the opening of untreated inner wood to fungal attack. Since wood-boring insects can carry spores and hyphae of sapwood-staining fungi into the logs, even through areas with attached bark, logs may need to be sprayed with a mixture of chemicals that control both insects and fungi.

Stain and decay in lumber are normally controlled at sawmills, collection points, and drying yards by dryingthe wood as rapidly as possible below 20 percent mois-ture content. Lumber to be air dried may be treated with fungicidal solution by dip or spray before the dry-ing period begins. Sometimes an insecticide is mixed into the solution if insects are likely to be a problem

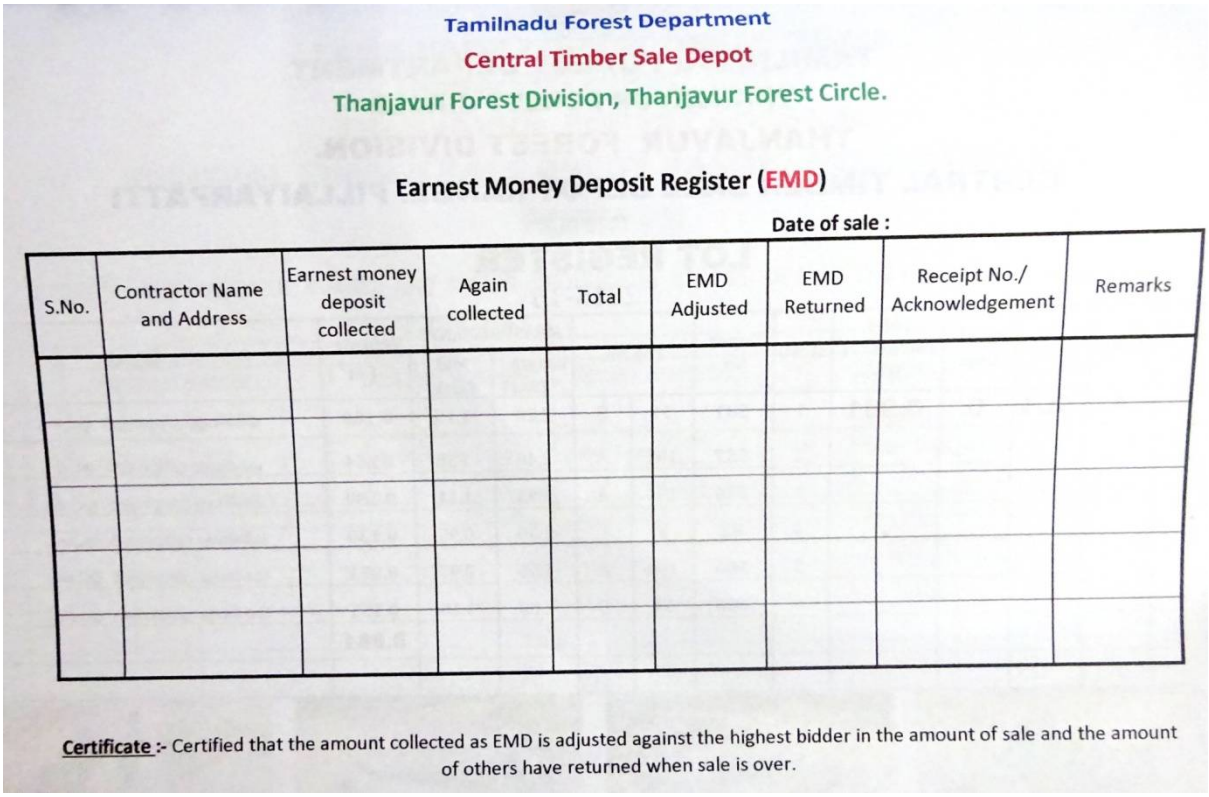
Treating for Insect Control

All insects that cause damage to sound (non decayed) lumber during storage will be either beetles or termites. Losses from termites can be much higher, al-though most of this loss occurs in wood in buildings; nevertheless, termites can damage lumber stored for some time in contact with the soil. Treatment may be needed to control insect damage in both dry and greenwood, regardless of the wetness or dryness of the storage location. The principal beetles that attack stored wood vary in their need for moisture. Ambrosia or pinhole beetles in-vade green or partially dried wood but usually are only a minor hazard in lumber stored away from forested areas or sawmills.

Among the most troublesome and damaging insects to stored lumber are those belonging to the true powder-post beetle group because they infest wood after it is dry..The other principal insect that might attack stored lumber is the termite. There are two general types of termites: subterranean and dry wood. Practically all woods are susceptible to their attack. Subterranean termites are by far the most prevalent type in the United States. They must have contact with some source of moisture, almost always the ground. Dry wood termites occur only in limited areas. Dry wood termites and powder-post beetles are the only insects that primarily attack dry wood. Properly applied treatments that are commercially available generally provide protection to stored lumber against powder-post beetles and termites. Environmentally safe boron compounds such as boric acid and borax are toxic to many wood-destroying insects and have been successfully used in the wood industries Lumberis immersed for 1 min in a borate solution and stored under cover for 7 days. Storage permits the borate to thoroughly diffuse through and penetrate the wood and ensures excellent protection from damage by powder-post beetles. There is also considerable protection from damage by termites and brown-rot decay fungi. It is important to realize that the dip treatments described here apply only to the protection of lumber in storage. Preservation of wood for use requires different types of solutions and methods of application. For wood that might be treated only because of the danger of subterranean termites, a more efficient method of protecting the lumber is to treat the ground under the storage piles or sheds.

Earnest Money Deposit Register.

During the proceedings of the sale of timber a sum of money will be collected from the buyer confirming the earnest participation of the buyer in the sale and recorded in the Earnest Money Deposit Register.



Tamilnadu Forest Department

Central Timber Sale Depot

Thanjavur Forest Division, Thanjavur Forest Circle.

Earnest Money Deposit Register (EMD)

Date of sale :

S.No.	Contractor Name and Address	Earnest money deposit collected	Again collected	Total	EMD Adjusted	EMD Returned	Receipt No./ Acknowledgement	Remarks

Certificate :- Certified that the amount collected as EMD is adjusted against the highest bidder in the amount of sale and the amount of others have returned when sale is over.

Form VI

After sale was conducted the sale of timber and other produce , including drift and waif wood and confiscated forest produce collected by government agency the details will be entered in Form VI as in the fallowing model form.

TAMILNADU FOREST DEPARTMENT
THANJAVUR FOREST CIRCLE
THANJAVUR FOREST DIVISION.
CENTRAL TIMBER SALE DEPOT RANGE. PILLAIYARPATTI
FORM - VI

Sales During the month of ..... Timber and other Produce out and collected by government Agency

Code Sections : 5, 52, 53, 58, 69, 134 and 149

39 Place of sale	Sl .No. in Form V	Description of timber And other produce	No Of Quantity	Cubic Metre or Other Unit	Rate	Total Amount Of sale	Amount Actually Paid	Balance	Amount	Sub -Head	No of logs Places Removed	Number sold But Remaining Unremoved	Remarks

Form VII

Dryage of the wood in the depot is recorded in Form VII by the Range officer. It is generally maintained in the sandal wood depot where dryage is strictly and precisely accounted.

Form VIII

Revenue realized from the sale of timber and other forest produce which were cut, collected and removed from the forest by the consumers or purchasers including pasture during the month will be entered in Form VIII

TAMILNADU FOREST DEPARTMENT
THANJAVUR FOREST CIRCLE
THANJAVUR FOREST DIVISION.
CENTRAL TIMBER SALE DEPOT RANGE. PILLAIYARPATTI

FORM - VIII

Revenue Forms Timber and other produce cut, collected and removed from the forest by counsumers or purchasers inculding pasture during the month of .....

FORM No 8 [Code Section 34,45,57,58,59,134,135 and 149.]

Forest Range.	Locality	PRODUCE REMOVED		Rate.		Amount of Revenue		Amount actually collected during the month.		Balance.		TOTAL REALIZED UNDER EACH BUDGET SUB-HEAD			Remarks
		Description.	Number or quantity.									Amount.		sub-head.	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	(11)
		Brought forward.		Rs.	P.	Rs.	P.	Rs.	P.	Rs.	P.	Rs.	P.		

Form IX

After sale of timber , details of outstanding of the revenue realized from the sale amount is entered in Form IX and consolidated periodical return will be submitted to the District Forest Officer by the Range officer .

TAMILNADU FOREST DEPARTMENT
THANJAVUR FOREST CIRCLE
THANJAVUR FOREST DIVISION.
CENTRAL TIMBER SALE DEPOT RANGE. PILLAIYARPATTI

FORM - IX

OUTSTANDING ON ACCCOUNT OF REVENUE FOR THE MONTH OF .....

FOREST DEPARTMENT. TAMIL NADU THANJAVUR DIVISION PILLAIYARPATTI RANGE

FORM No 9 SECTION 5 ,69 AND 149

Sl NO.,	NAME	Particulars	Outatanding on the 2018		RECOVERIES DURING THE MONTH			Current revenue not collected during the month	Budget Sub head	Date from which Each item is Outstanding	Remarks
					Number of Item in cash book	Amount					
	1	2	3		4	5		6	7	8	9
			Rs	p.		Rs	p.				

Form I Red permit.

It is a transit permit used when the sold timber is removed from the depot (Goverment land) to private land .

Tamilnadu Forest Department

Thanjavur Forest Circle, Thanjavur Forest Division

Form - I Red Permit

வனத்துறை, தமிழ்நாடு

Counterfoil to be sent to the officer in-charge of the forest.

காட்டுக்குடையவருடைய ஆபீஸருக்கு அனுப்பவேண்டிய பிரதி

Form I பாரம் I

Pass No., அனுமதிச்சீட்டு நெம்பர்

Pass for the export/Transport of Timber/Red Sanders/Sandalwood from Government land/ Depots

சர்க்கார் நிலங்களிலிருந்து / டிப்போக்களிலிருந்து வெட்டுமரத்தை / சிவப்பு சந்தன மரத்தை / சந்தன மரத்தை ஏற்றுமதி செய்ய / கொண்டுபோக அனுமதிச்சீட்டு.

(Under Section 35 of the Madras Forest Act.1882)

(1882 வருடத்திய சென்னை பாரஸ்ட் ஆக்ட் செக்சன் 35)

1.Name and residence of the person to whom the pass is granted

அனுமதி கொடுக்கப்பட்டவருடைய பெயரும் வாசஸ்தலமும்

2.Quantity msT

3.Description of Timber/ Red Sanders/ Sandalwood

வெட்டுமரத்தின் ∴ ரெட் ஸாண்டர்ஸ் என்னும் சிவப்பு சந்தன மரத்தின் ∴ சந்தன மரத்தின் விபரம்

4.Fees paid, if any, கட்டணங்கள் செலுத்தப்பட்டால் அது.

5.Marks, if any, on the Timber/ Red Sanders/ Sandalwood

வெட்டுமரத்தின் ∴ ரெட் ஸாண்டர்ஸ் என்னும் சிவப்பு சந்தன மரத்தின் ∴ சந்தன மரத்தின் மேல் அடையாளங்களிருந்தால் அது.

6.From what Forest or Depot removed.

எந்தக் காட்டிலிருந்து அல்லது டெப்போவிலிருந்து கொண்டுவரப்பட்டது.

7.To what Place removed. எந்த இடத்திற்கு கொண்டுபோகப்படுகிறது.

8.Route. top

9.Time allowed. கொடுக்கப்பட்ட கால அளவு

10.Remarks. குறிப்பு :

Date : தேதி :

Camp : முகாம் :

Signature of the issuing officer

கொடுப்பவர் கையெழுத்து

Designation. உத்தியோகம்

After the wood is despatched a check list will be prepared to compare and correlate timber accounting in the fallowing form.

CENTRAL TIMBER SALE DEPOT, PILLAIYARPATTI, THANJAVUR.

DETAILS FOR RELEASING OF SOLD LOTS .

CHECK LIST CUM COMPARATIVE STATEMENT

1 Reference to DFO.File No :

2 Date of Sale :

3 Depot/Range : CTD, PILLAIYARPATTI

4 No.of Lost&Lot Number :

5 Name of the Contractor :

6 Full Sale Amount :

7 1/3 Sale Amount Collected :

8 Date of Confirmation :

9 Collection Details :

Date	Lot Details	2/3rd Amount	GST 18% Amount	Income Tax 2.5%	Total Amount	Remarks
	Grand Total					

10 CF 61 Receipt No.&Date (if Collected in Cash) :

11 Date of Receipt of DD(s) :

12 Date of Remittance of DD(s) :

13 Reference toRegister of DDs :

14 Reference to Cash Book :

Main Cash Book

ST Cash Book

IT Cash Book

PageNo/Item No	
Dr.Item	Month
By D.F.O/ By Ranger	

15 Date of Release Order

16 Release Due date

17 Date of Actual Released

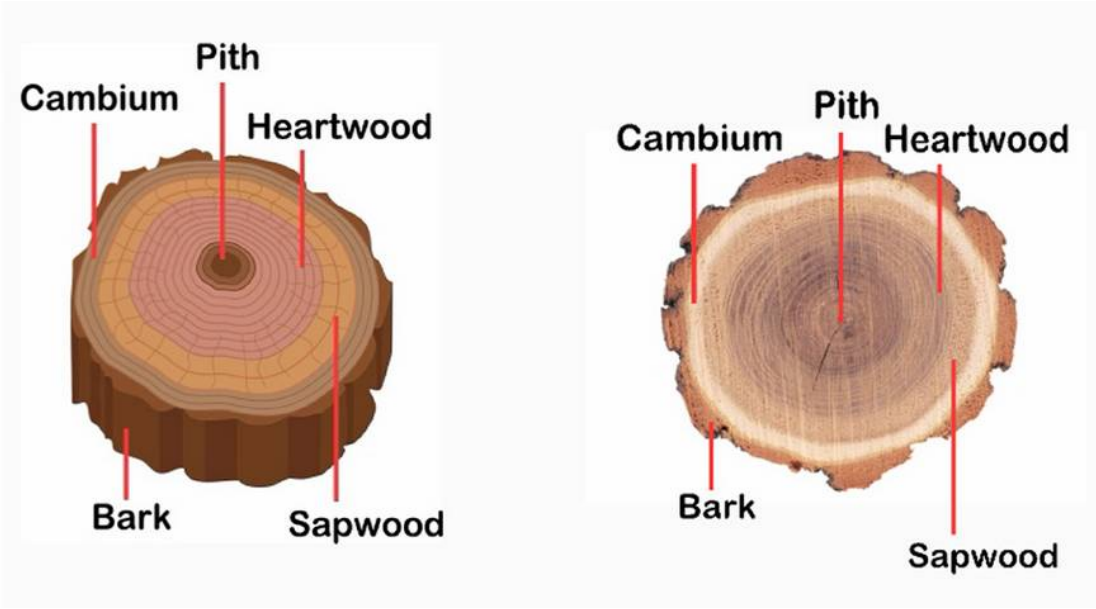
Form I Red Permit No

CF 61 Receipit No

2. WOOD TECHNOLOGY.

2.1 Gross Features of wood

2.1.1 Pith, Heart wood, Sapwood.



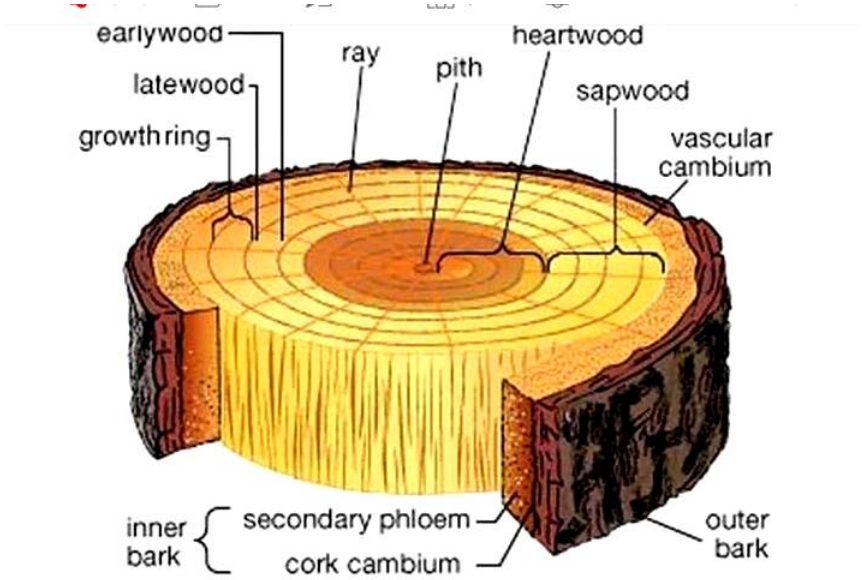
Pith (Medulla): Pith is moderately huge and prominent, composed of parenchymatous cells and is placed at the centre. In several stems the vital part of the pith is damaged during growth, but the pith in nodes will be retained. The pith cells primarily serve as storage tissue.

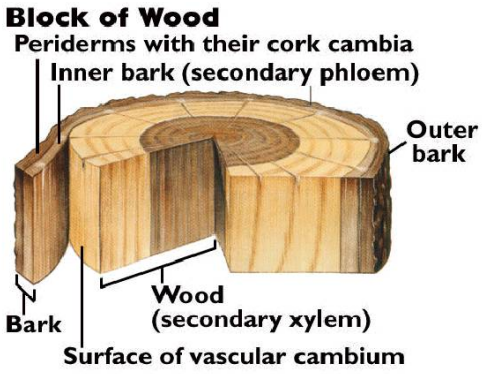
In dicotyledons, pith is located in the center of the stem. In monocotyledons, it extends also into flowering stems and roots. The pith is encircled by a ring of xylem; the xylem, in turn, is encircled by a ring of phloem.

Formation: The pith of young stem contains chloroplast whereas the older stems hold profuse leucoplast. Pith is composed of soft, spongy parenchyma cells, which store and transport nutrients throughout the plant.

Function: Basically, the function of pith is to store nutrition, at the same time, its parechymatous eminence enables it to take accountability of transporting nutrients to outer tissues in the plant.

- Main function is Storage of food.
- Another function of the pith of a plant is to provide support to a large plant that is undergoing secondary growth





- a. Secondary Xylem to inside of VC accumulates in annual growth rings
- b. Secondary Phloem to outside of VC and inside older secondary phloem and periderm is crushed and is eventually lost via periderm

Heart wood

Heartwood, also called **duramen**, dead, central wood of trees. Its cells usually contain tannins or other substances that make it dark in colour and sometimes aromatic. Heartwood is mechanically strong, resistant to decay, and less easily penetrated by wood-preservative chemicals than other types of wood. One or more layers of living and functional sapwood cells are periodically converted to heartwood.

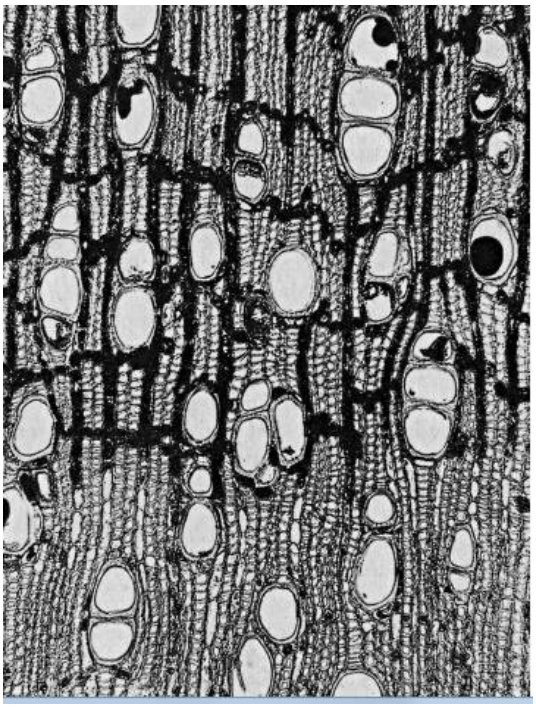
Heartwood formation usually begins in some species of *Eucalyptus* at about 5 years; in several species of pine at 15 to 20 years; in European ash at 60 to 70 years; and in beech at 80 to 100 years (Dadswell and Hillis, 1962). In a few species (e.g., *Alstonia scholaris*) heartwood may never form.

Changes during Heartwood Formation

The most critical change during conversion of sapwood into heartwood is the programmed death of ray and axial parenchyma cells. Other important changes include a decrease in the metabolic rate and enzymatic activity, starch depletion, darkening and accumulation of extractives in the xylem,

During heartwood formation a wide variety of extractive substances, including tannins, dyestuffs, oils, gums, resins, and salts of organic acids accumulate in cell lumens and walls. Polyphenols, aromatic compounds with one or more hydroxyl groups, are among the most important heartwood extractives (Fig. 3.24). Deposition of extractives results in a dark-colored wood. However, the color of heartwood varies among species and with the types of compounds deposited.

In many conifers and angiosperms, parenchyma in the transition zone synthesize secondary metabolites (often termed *extractives* in the forest products and wood anatomy literature). These compounds are deposited in the walls of neighboring cells and often fill parenchyma lumen, imparting properties of decay resistance, color, and reduced permeability to the heartwood.



Sapwood

Sapwood is the living part of a tree where the sap and water flow. All wood initially grows as sapwood. As the tree ages, the innermost layers of sapwood turn to heartwood, which is no longer living and does not transport nutrients. Sapwood usually has a lighter color than the heartwood that it surrounds

The xylem, or **sapwood**, comprises the youngest layers of wood. Its network of thick-walled cells brings water and nutrients up from the roots through tubes inside of the trunk to the leaves and other parts of the tree.

S.No.	Sapwood	Heatrwood
1	It is outer wood of an old stem.	It is the central wood of an old stem.
2	It is light coloured.	Heartwood is dark coloured.
3	Living cells are present.	Living cells are absent.
4	Sapwood is the functional part of the secondary xylem or wood.	Heartwood is the non-functional part of secondary xylem.
5	The tracheary elements are not plugged by tyloses. The tracheary elements are not plugged by tyloses.	The tracheary elements are plugged by tyloses. Tracheary elements have deposition of tannins, resins, gums, etc.
6	Sapwood or alburnum is lighter.	Heartwood is heavier.
7	It is less durable because it is susceptible to attack by pathogens and insects.	It is more durable due to its little susceptibility to the attack of pathogens and insects.

2.1.2. Bark, Early wood , Late wood, Growth ring.

Bark is the outermost layers of stems and roots of woody plants. Plants with **bark** include trees, woody vines, and shrubs. **Bark** refers to all the tissues outside the vascular cambium and is a nontechnical term. It overlays the **wood** and consists of the inner **bark** and the outer **bark**.

As wood is laid down inside a shoot, a layer of cells near the outer side begins to divide and produce cork cells. The walls of these cells soon get heavily thickened with a waterproof substance. The cells die and form **bark**. Over the years the **bark** is constantly added to form the inside of the tree.

The inner soft **bark**, or bast, is produced by the vascular cambium; it consists of secondary phloem tissue whose innermost layer conveys food from the leaves to the rest of the plant. The outer **bark**, which is mostly dead tissue, is the product of the cork cambium'

Earlywood

Earlywood develops in the spring when rain and nutrients from the soil are abundant and days are getting long. New growth makes up the better part of the ring, and in many *woods*, it is lighter in color than latewood, which develops towards the end of summer before the tree goes dormant (in harsh climates).

Late wood.

The part of the **wood** in a growth ring of a **tree** that is produced later in the growing season. The cells of **late wood** are smaller and have thicker cell walls than those produced earlier in the season.

Sl.No	Earlywood or Spring wood	Late wood or Autumn wood
1	Formed during spring season.	Formed during winter season.
2	Formed early in a year.	Formed after the early wood.
3	Consists of xylem tissues with wider vessels.	Consists of xylem elements with narrow vessels.
4	Produced more in amount.	Produced less in amount.
5	Less dense.	More dense.
6	A broad zone of wood.	A narrow zone of wood.
7	Not as strong as late wood.	Stronger than early wood due to larger volume of wall materials.

Growth ring

Growth ring, in a cross section of the stem of a woody **plant**, the increment of wood added during a single **growth** period. In temperate regions the **growth** period is usually one year, in which case the **growth ring** may be called an "**annual ring**." In tropical regions, **growth rings** may not be discernible or are not **annual**.

Reading between the Rings

A cross section of a tree shows much more than its age! Diameter growth is particularly sensitive to fluctuations in the environment: moisture in the soil and air, temperature, and sunlight. Very broad rings generally indicate a good growing year. The tree apparently received everything it needed.

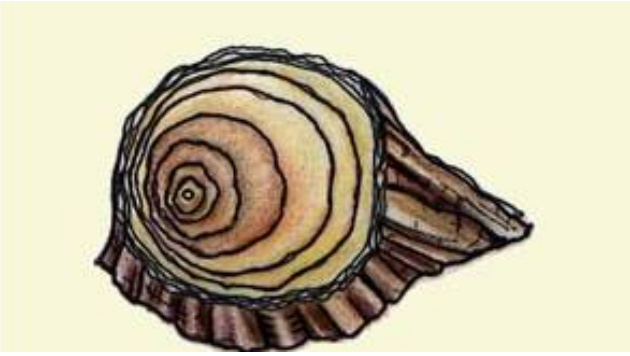
The growth rate of a tree can be compared to the growth of a child. A young sapling grows much faster than an adult tree. A cross section of an older tree shows rings that are quite broad at the beginning of its life (in the centre) but that become progressively smaller. An old tree produces very narrow rings and its diameter and height growth are considerably slower.

Look carefully at the pictures and read the explanations to understand what may have caused the cross section.

Narrow rings do not only signify a lack of sun or water. A forest fire may have damaged the tree's crown and slowed its growth. Defoliation by insects or fungi can have the same effect.

After several years, the tree gained strength and returned to normal growth.

This tree had a rough time during its first ten years! Maybe someone helped it by cutting the large trees around it to give it more light.



Trees don't have their heart in the right place! This tree shows off-centre growth. If the tree was in a location exposed to high winds, its wood would grow faster (wider rings) on the side away from the wind than on the side facing the wind.

This cross section may also come from a tree that was leaning. The tree formed reaction wood (compression wood) that enabled it to straighten up. The wider rings are on the underside of the leaning trunk because growth was faster there.

The wave in the ring indicates that there was a branch or knot in the stem

Trees in Tropical Countries

Annual rings generally exist in trees where the climate halts growth at some point during the year. In temperate countries, winter causes this shutdown. In tropical countries, it is the dry season. Growth begins again in the spring or rainy season.

But what happens to trees growing in countries where there is no alternation between growth and rest periods?

For example, a country where it rains all year long! Remember that all trees grow by adding successive rings. So in such an area, the beginning and end of the growth period may occur any time during the year, depending on the local conditions.

Some trees in tropical forests, manage to create several dozen very thin rings in a year, and never the same number from one year to the next. It is often difficult, even impossible, to distinguish them with the naked eye. In such cases, it is extremely hard to determine the age of the tree.

Ring Porous Wood and Diffuse Porous Wood| Plants

Sl. No	Ring porous wood	Diffuse porous wood
1	The vessels are of different diameter.	The vessels are more or less equal in diameter.
2	The vessels are not uniformly distributed throughout the wood	The vessels are uniformly distributed throughout the wood.
3	Vessels with wide and smaller	Vessels with more or less equal diameter are

	diameter are formed in the early and the later part of the growth season respectively.	formed throughout the growth ring.
4	Vessels with wide diameter of early wood and vessels of smaller diameter of late, summer or autumn wood are distinguishable.	Vessels of early wood and late wood are indistinguishable.
5	The development of vessel is sudden and rapid.	The development of vessel is slow.
6	The vessels are longer in length than those of diffuse porous wood.	The vessels are shorter in length than those of ring porous wood.
7	The rate of transport of water in plant with ring porous wood is ten times faster than those with diffuse porous wood.	The rate of transport of water in plants with diffuse porous wood is slower than those with ring porous wood.

2.2 Minute Structures of wood

2.2.1 Trachieds, Fibers and vessels

Tracheid, in botany, primitive element of xylem (fluid-conducting tissues), consisting of a single elongated cell with pointed ends and a secondary, cellulosic wall thickened with lignin (a chemical binding substance) containing numerous pits but having no perforations in the primary cell wall. At functional maturity, the cell is dead and empty; its former protoplast is represented, if at all, by a warty layer on the wall. Tracheids serve for support and for upward conduction of water and dissolved minerals in all vascular plants and are the only such elements in conifers and ferns. See also vessel.

Vessel elements play a crucial role in the transport of water from roots to leaves.

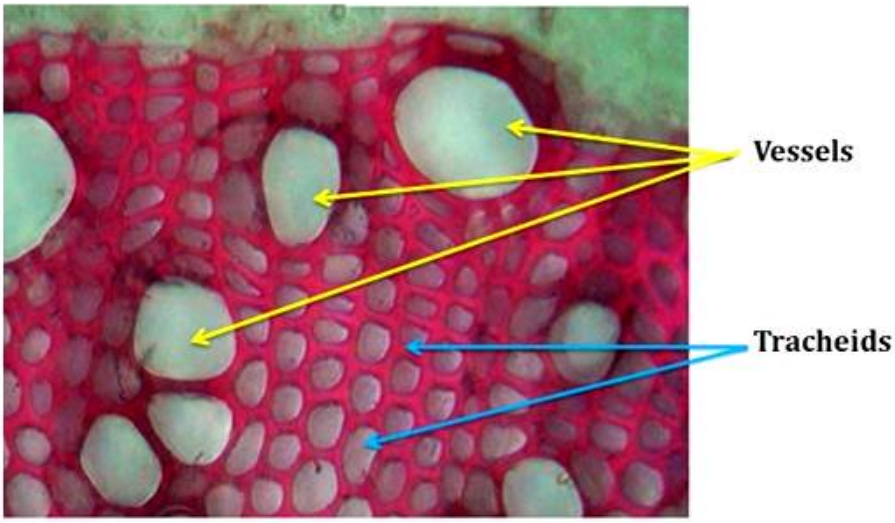
Fibers are one of the components of sclerenchyma tissue, along with shorter, thick-walled sclereids and associated with the xylem and phloem tissue for support **plant**.

A **vessel** element or **vessel** member (trachea) is one of the cell types found in xylem, the water conducting tissue of **plants**. **Vessel** elements (tracheae) are typically found in flowering **plants** (angiosperms) but absent from most gymnosperms such as conifers.

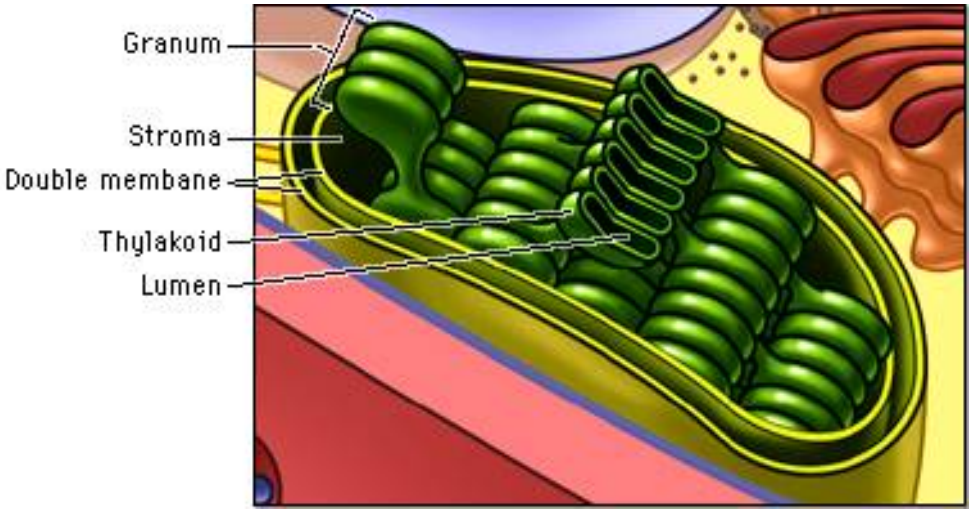
Fibers are elongate cells with tapering ends and very thick, heavily lignified cell walls. **Fiber** cells are dead at maturity and function as support tissue in **plant** stems and roots. ... The densely-packed **fiber** cells greatly increase the hardness and density of angiosperm woods.

Tracheids and vessels are the two water conducting elements found **in the** xylem. **Tracheids** are the major conducting element in ferns and gymnosperms. **Vessels** are only present in angiosperms. ... The main **difference between tracheids and vessels** is their diameter and the efficiency in water conduction

S. No.	Vessels	Tracheids
1	Vessel is a syncyte , formed by the piling up of many cells	Tracheids are not syncyte, they are individual cells
2	Individual cells (vessel elements) are shorter than tracheids.	Cells are longer than tracheids.
3	Advanced than tracheids	Primitive than vessels
4	Average length is 10 cm.	Average length is 1mm
5	Cells are are broader than tracheids	Cells are narrower than vessels
6	Cell lumen is large.	Cell lumen is small
7	Cells are circular in cross section	Cells are polygonal in cross section
8	Secondary cell wall is thinner than tracheids	Secondary cell wall is thicker than vessels
9	Vessel cells are with diagonal and transverse end walls	Cells with tapering end walls
10	Vessel elements are connected in an end to end fashion.	Tracheids are connected laterally
11	End wall with perforation plate	End wall without perforation plate
12	Vessels usually confined to Angiosperms	Trachieds present in all vascular plants (Pteridophytes, Gymnosperms, Angiosperms)
13	Lower surface to volume ratio than tracheids	Higher surface to volume ratio than vessels
14	More efficient in water conduction than trachieds	Less efficient in water conduction than vessels
15	Main conductive elements in Angiosperms	Mani conductive elements in Pteridophytes and Gymnosperms



CS of Dicot Stem showing Vessels & Tracheids



Cloroplast

Fibers

Fiber cells are present in many different plant parts. Botanically fibers are divided according to their position within or outside the xylem. Libriform fibers and fiber tracheids, being a part of xylem, are called xylary fibers. Another type of xylary fiber, present in tension wood, is the gelatinous or mucilaginous fibers. Xylary fibers constitute an integral part of the xylem and develop from the same meristematic tissues as do the other xylem components. Extraxylary fibers (i.e., the fibers localized outside xylem) can be found within the cortex (cortical fibers), phloem (phloem or bast fibers), or at the periphery of the vascular bundles (perivascular fibers).

Possessing distinct tensile strength, elasticity, and flexibility, fiber cells can be discriminated from other plant tissues and be extracted for industrial purposes. The

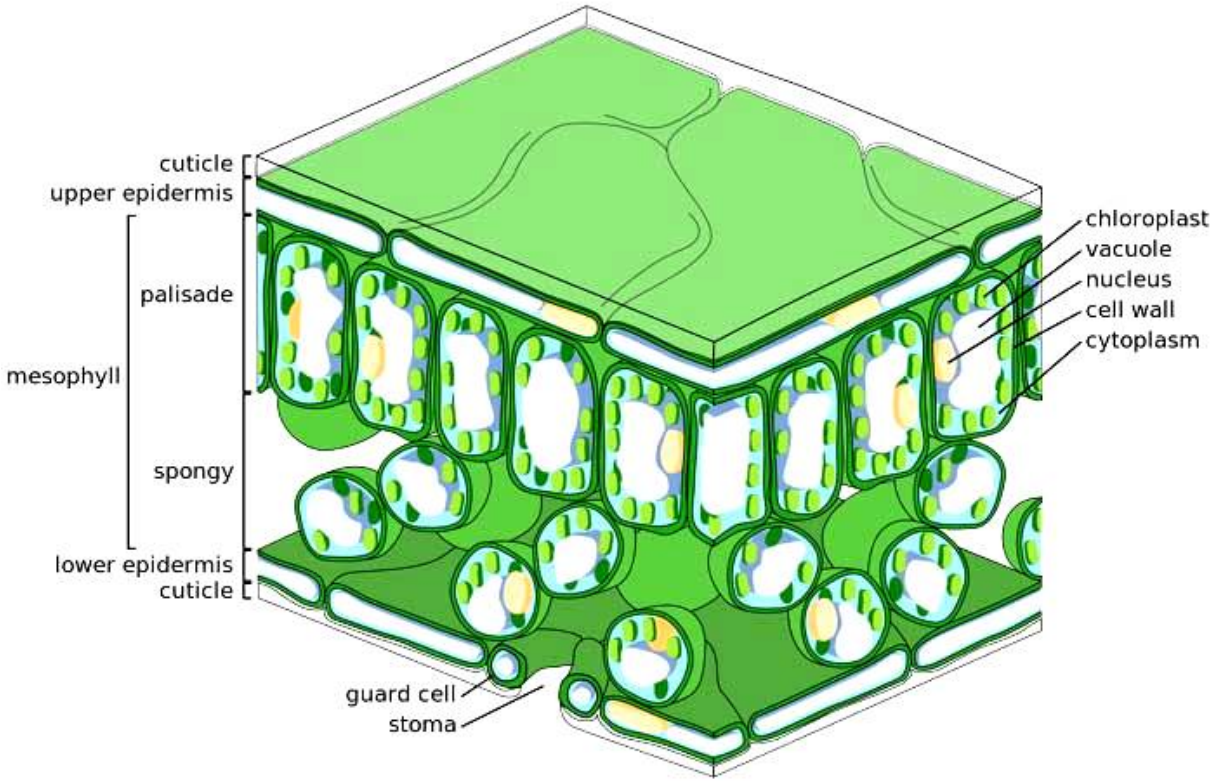
sclerenchyma fibers may occur singly as idioblasts, but more usually they occur in bundles. These fiber bundles include the dicotyledon bast fiber crops of commercial interest known as soft fibers: flax (*Linum usitatissimum*), hemp (*Cannabis sativa*), jute (*Corchorus* spp.), ramie (*Boehmeria nivea*), and kenaf (*Hibiscus cannabinus*). Bast fiber bundles run longitudinally along the stem from bottom to top and reach almost the full length of the plants, which may be 3 meters or more for hemp. The leaf fibers, also known as hard fibers, are the agglomeration of fiber cells with vascular elements and are extracted from the fibrovascular system of leaves of monocotyledons: sisal (*Agave* sisalana), abaca (*Musa textilis*), yucca (*Yucca* spp.), henequen (*Agave fourcroydes*), *Phormium tenax*, some palms (e.g., raffia (*Raphia ruffia*), etc). Fibrous tissues may also be obtained from other plant parts such as stalks and roots of grasses (sugar cane (*Saccharum officinarum*) bagasse, reeds, straws) or the mesocarp (coconut (*Cocos nucifera*) coir fiber).

2.2.2 Parenchyma, rays and resin canals

Parenchyma

It can define as the simple permanent tissue, which is usually thin-walled and functions as a "**ground tissue**" by forming a packaging material of all the non-woody structures like leaves, roots and stems.

Structure of Parenchyma Cells



Plant parenchyma cells are believed to be the precursor of differentiated and specialized cells and tissues. The parenchyma is the simplest among the three types of plant cells because they only have a very thin layer of cell walls.

- In terms of shape, they are classified to be *isodiametric*. Because their walls are very thin, the shape of these cells is believed to be governed by the function of pressure and tension around the cells. Generally, cells always maximize their volume capacity and would have to distribute the pressure all over the structure; hence, they would have to assume a somewhat spherical shape.
- In general, parenchyma cells carry huge amounts of chloroplasts, ribosomes, ER, and Golgi bodies. Depending on what type, they may carry starch, proteins, fats, pigments, and even crystals.
- The thin cell walls of parenchyma cells are composed of cellulose, hemicellulose, and calcium pectate. The plasmodesmata and the middle lamella are also commonly present.

In some few cases, however, parenchyma cells can have thick walls (i.e. endosperm of date palm, coffee, and persimmon). The sugars present in these thick walls become the nutrients for the germinating embryo.

Furthermore, some parenchyma cells may also develop lignified or secondary walls and may even be indistinguishable from sclerenchyma cells.

Distribution of Parenchyma Cells in Plants

Parenchyma cells occur throughout the plant structure. They may either be present as an independent mass of tissue or be linked with other cells in different tissues. These cells are important constituents of various tissues in plants such as pith, cortex of roots and stems, as well as the mesophyll in the leaves. They can also be found in the transport tissues xylem and phloem.

- Basically, the arrangement of parenchyma in different plant tissues greatly depends on their function. For instance, parenchyma cells in the spongy mesophyll tend to have large intercellular spaces in order to facilitate their function of greater exposure for carbon dioxide.
- In terms of arrangement, mature parenchyma cells are generally arranged with little intercellular spaces between them. However, there is still always a great difference as regards to the arrangement of these cells in plants.

Functions of Parenchyma Cells

1. Storage

Because of their very large intercellular space, parenchyma cells are suitable for storage purposes. Parenchyma cells, known as storage parenchyma, possess no chlorophyll and instead are composed of the stored food product (usually starch).

- Instead of the chloroplasts, these cells harbor the specialized structure called *amyloplasts.* An example of this specialization is the high amount of starch present in tubers (root crops) such as potatoes and cassava.
- With their large intracellular spaces, they are also capable of storing water. Such type of parenchyma cells is present in succulent plants.

2. Transport

Some parenchyma cells are adapted to function for the transport of nutrients, substances, and other chemicals. Others, known as transfer cells, are used to transport huge quantities over short distances.

- These parenchyma cells have several modifications like the presence of ridges and folds order to increase surface area for absorption. This type of parenchyma also has thicker yet non-lignified secondary cell wall.
- Some (known as sieve elements) transport a relatively lesser amount but over long distances. Furthermore, some these cells are responsible for transporting light from the surface of the soil to the underground.

3. Photosynthesis

As alluded to earlier, some parenchyma cells carry huge amounts of chloroplasts for photosynthesis. These cells collectively make up the chlorenchyma tissue present mostly in the stem and leaves of plants.

- The chlorenchyma is made up of two parts:the palisade and the spongy chlorenchyma.
- The palisade chlorenchyma is made of parenchyma cells with small intercellular spaces. In this way, the plant is able to maximize its surface area to acquire sunlight.
- On the other hand, the spongy chlorenchyma has cells with huge gaps in distances in order to facilitate aeration.

4. Gas Exchange

Group of parenchymal cells compose the aerenchyma tissue, a type of tissue specialized for giving the plant the ability to float The tissue is made up of loosely arranged and mechanically weak parenchyma cells; therefore, the tissue lacks stiffness.

- However, this is definitely an advantage since too much thickness may drag the plant down and cause suffocation.
- An example of this is the root system of the willow root.

5. Protection

Despite their simple structures, parenchymal cells can also function for plant protection. For instance, gymnosperms have the so-called folded parenchyma which is composed of cells with various invaginations to their edges.

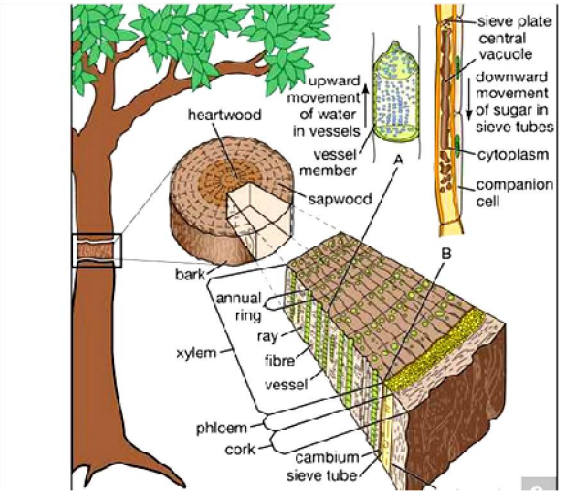
- This modification creates coarser leaf surfaces that help in deterring predators.

6. Serve as Precursor to Other Cell Types

Parenchyma cells are the least differentiated cell and therefore have the ability to transform to other cell types before, during, and even after development. Aside from that, these cells are considered to be *totipotent*. Meaning, all types of cell fates is possible.

- A specialized type of tissue, called the *meristematic parenchyma*, is composed of group of parenchyma cells that have retained their dividing ability. For instance, when a plant gets wounded, the surrounding parenchyma cells may develop to replace the lost cells.
- The parenchymal cells that make up this tissue are immature, multi-nucleated, and non-vacuolated.

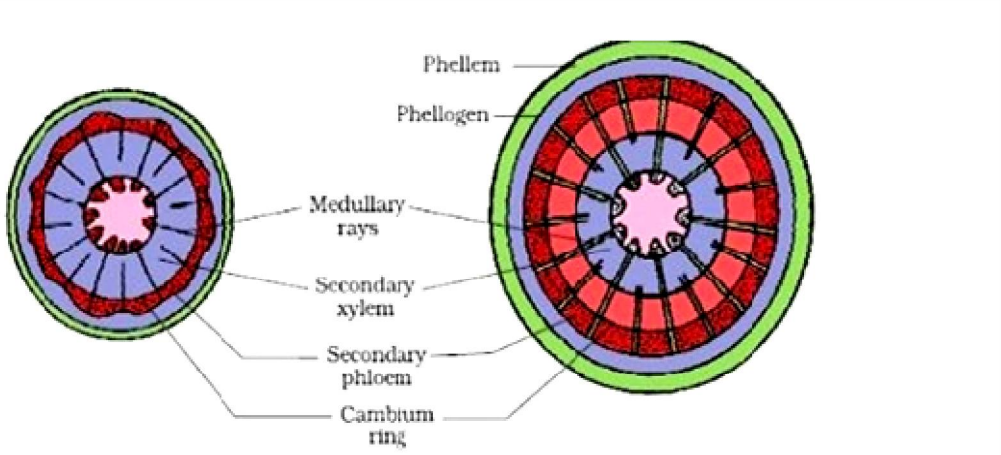
Ray parenchyma cells occur in wood **rays**, the structures that transport materials laterally within a woody stem. Parenchyma cells also occur within the xylem and phloem of vascular bundles. The largest parenchyma cells occur in the pith region, often, as in corn (Zea) stems, being larger than the vascular bundles.



Unlike the apical meristems, which consist of a population of similar cells, the cambium consists of two different cell types; the fusiform initials and the ray initials. The fusiform initials are elongated tapering cells that give rise to all cells of the vertical system of the secondary phloem and xylem (secondary tracheary elements, fibres, and sieve cells and the associated companion cells). The ray initials are isodiametric cells—about equal in all dimensions—and they produce the vascular rays, which constitute the horizontal system of secondary tissues; this horizontal system acts in the translocation and storage of food and water.

Formation of secondary medullary rays:

Secondary medullary rays are vertical plates of parenchyma cells running radially through the cylinder of vascular tissue in the stems and roots of plants. The extensions of the medulla, between the vascular bundles, are called Medullary rays. Medullary rays store and transport food materials. They are multi seriate and take part in the lateral conduction of water. These are found in dicot stems only.



(i) Secondary medullary rays are produced by the vascular cambium and terminate in xylem and phloem tissues. Medullary rays store and transport food materials. Medullary rays are strips of parenchyma present between vascular bundles of dicot stem. They separate xylem and phloem bundles.

(ii) Secondary medullary rays are formed from the cambium ring. They are formed by the activity of fascicular cambium. They serve as a link between the pith and cortex. They are also known as pith rays and vascular rays.

(iii) During the process of the division of cambium, the cambium cuts out cells on both the outer and inner sides. They are any of the vertical plates of parenchyma cells running radially through the cylinder of vascular tissue in the stems and roots of plants.

(iv) The cells of some particular places of a cambium ring produce parenchyma tissue instead of xylem or phloem. They are produced by the vascular cambium and terminate in xylem and phloem tissues.

(v) The narrow bands of parenchyma tissue run rapidly through secondary xylem and secondary phloem tissues.

(vi) These narrow bands of parenchyma tissues are known as secondary medullae rays. Each may be one too many cells in width.

Secondary medullary rays may be differentiated into xylem medullary rays and phloem medullary rays. Primary medullary rays occur in young plants and in those not showing secondary thickening; they pass from the cortex through to the pith. These medullary or pith rays are essential for the radial conduction of the water, minerals and other organic substances. They transport the substances from the center to the periphery. They perform various functions like food storage, storage of tannins, transport of food and water, gaseous exchange, etc.

Resin:

In polymer chemistry and materials science, *resin* is a solid or highly viscous substance of plant or synthetic origin that is typically convertible into polymers. *Resins* are usually mixtures of organic compounds.

Phenol-formaldehyde- C8H6O2

Epoxy resin

Acrylate - $C_{21}H_{25}ClO_5$

Gum – 2.45% of proteins, 0.85% of fats and 92.36% of carbohydrates.

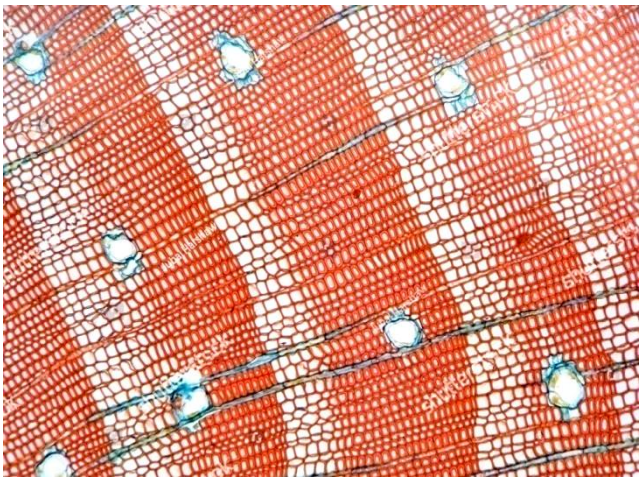
Chemical formula $C_{35}H_{49}O_{29}$ (monomer)

(A **monomer** is a molecule that is able to bond in long chains. ... This linking up of **monomers** is called **polymerization**. **Polymer** means many **monomers)**

Resin canals or **resin ducts** are elongated, tube-shaped intercellular spaces surrounded by epithelial cells which secrete **resin** into the **canal**. These **canals** are orientated longitudinally and radially in between fusiform **rays**. They are usually found in late wood: denser wood grown later in the season.

Normal resin canals exist naturally in the wood of the genera *Picea*, *Larix*, *Pinus*, *Pseudotsuga* and *Shorea*.

Traumatic resin canals may be formed in wounded trees that don't have normal resin canals. Wounding occurs from either fire, freezing or mechanical damage. These canals are irregularly shaped compared to normal resin canals



Resin ducts-Cross section of pine stem

The **resin** protects the plant from insects and pathogens. **Resins** confound a wide range of herbivores, insects, and pathogens, while the volatile phenolic compounds may attract benefactors such as parasitoids or predators of the herbivores that attack the plant.

Pine needle resin serves as defence against insects and other animals, which confront the distasteful substance when boring into the conifer's leaves. The **resins** may disrupt the feeding, digestion or metabolic **function** of the attacker.

Resin ducts are present in the stem, leaf and root **located** only in the phloem of the vascular bundles. They are tubular structures lined by a few layers of epithelial cells

These **canals** are orientated longitudinally and radially in between fusiform rays. They are usually found in late wood: denser wood grown later in the season. **Resin** is antiseptic and aromatic and prevents the development of fungi and deters insects.

Resin secreted and oozing through **resin** ducts, and often escaping through the bark of coniferous **trees**, serves more of a protective function in reaction to injury or attack by insects or pathogens.

Most **resin** used commercially **comes from trees** of the Pinaceae, legume families, and Dipterocarpaceae. Copals are a group of **resins** extracted from leguminous forest **trees** and are known for their hardness and high melting point.

There are three main **types of Resins** used today for use with Carbon Fibre, Fibre glass. These are Epoxy, Vinyl ester, Polyester **Resins**. Each has **different** characteristics and associated costs.

Resin formation occurs as a result of injury to the bark from wind, fire, lightning, or other cause. The fluid secretion ordinarily loses some of its more volatile components by evaporation, leaving a soft residue at first readily soluble but becoming insoluble as it ages.

Good electrical insulation, heat resistance and chemical resistance. Glass fiber-reinforced versions offer rigidity. Excellent in a variety of **properties** including heat and cold resistance, electrical insulation, flame-retardancy, adhesion, oil and solvent resistance, water repellency and ecological adaptability.

Epoxy **Resin** is a versatile material that's **used** in a wide variety of crafts. **Resin** casting is a fun way to accent your furniture, create jewelry and ornaments, etc. **Resin** starts as a liquid and then hardens, so you can pour it into moulds, or add items like dried flowers, insects, or leaves.

2.3 General properties

Colour of the wood

Colour of the wood is due to infiltration of chemical products. Colour is very variable feature and yet it has some diagnostic value. As a rule wood darken on exposure. This is due to chemical action which takes place under ordinary light and atmospheric condition

There are thousands of tree species around the world and potentially dozens if not hundreds of variants within species.

Environmental conditions can also have a *huge* impact on trees of the same species, even if they grow in a similar location. For example, the density, structure and colour of the timber from a Pine tree that grows in a darker, wetter part of the woods will differ from a Pine tree that grows in a lighter, drier part of the same woods. The age of a tree also affects the wood colour, density and structure of the timber.

All timbers, regardless of age, species, density and growing conditions have their own unique characteristics. For example, pine timbers can typically look pale and neutral when freshly sanded, the timber however, depending on species, inherently has a reddish, pink or yellowy characteristic. This often results in freshly sanded pine floors, turning a golden orange or yellow colour when treated with a 'clear' wood oil or varnish. In the same way, the natural timber colouration will influence the final colour of any coloured wood finish. For example, a natural cocoa brown stain will take on a warmer, golden-brown appearance when applied to pine.

Flourescence of the wood

Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation. It is a form of luminescence. In most cases, the emitted light has a longer wavelength, and therefore lower energy, than the absorbed radiation. The most striking example of fluorescence occurs when the absorbed radiation is in the ultraviolet region of the spectrum, and thus invisible to the human eye, while the emitted light is in the visible region, which gives the fluorescent substance a distinct color that can be seen only when exposed to UV light. Fluorescent materials cease to glow nearly immediately when the radiation source stops, unlike phosphorescent materials, which continue to emit light for some time after.

One of the best examples of fluorescence is found in Black Locust *(Robinia pseudoacacia)*, which is very similar to Mulberry *(Morus spp.)* in both appearance and weight. But one way to easily distinguish the two is by observing them under a blacklight; Black Locust will emit a strong yellow-green glow, while Mulberry will be non-reactive.

Here is a list of woods that exhibit some level of fluorescent properties when exposed to a black light:

Wood Species	Fluorescence notes:
Albizia	bright, uniform green
Coffeetree	bright uniform yellow/green
Olive	faint to medium yellow streaks in certain portions of heartwood
Padauk, African	faint to medium yellow/orange

Lusture of wood

Some timber have a characteristic way of reflecting light from the cell wall. This feature is known as lustre. Lustre can usually be seen on the longitudinal surface , and more on the longitunal – radial surface. Albizzia labbek has a very strong lustrous sheen which is enhanced by high polish.

"Sheen" has more to do with the quality of the unfinished wood surface: certain species exhibit a remarkable shininess, i.e., light reflectivity if planed and scraped very smooth and observed under bright light. The sheen tends to dull as the wood fibers' exposure to the atmosphere increases with time. It can be renewed by re-scraping the surface.

"Luster" is imparted to wood by use of a finish: varnish, polyurethane, lacquer, tung oil, etc. When properly applied, finishing materials enhance the beauty of the piece, and help to preserve the sheen imparted by scraping. Use of a finish also can give a perceived depth to the figure of the wood, as if you were looking at folds or wrinkles in the surface of the piece rather than a smooth plane.

Odour of the wood

Certain wood has characteristic smell (particularly when freshly cut) of their own that can be mistaken for that of any other wood. This smell is the result of some chemical deposition which will be more in the heart wood than in the sap wood. The unmistakable odour of teak , Camphor wood, Deodar wood, the distinct aroma of sandal wood, the resinous odour of pines are well known.

The odour may affect the value of wood favourably or adversely, according to its fragrance or disagreeableness.

Weight of the wood

The weight of the wood varies not only in different species but also in the same species. Among the various factors that give weight to wood, moisture content is the most important .

the moisture content may vary from about 30 to 200 per cent in gren timberand on exposure it loses the water considerably.

Woods are classified according to their weight in to

Very light

Light

Moderately light

Moderately heavy

Heavy

Very heavy.

Calculating green weight of wood

Since water conveniently weighs about 1 g/cm3 , variable with temperature, specific gravity was derived as an index metric to state the weight of other substances relative to water. The nice thing about using water as the reference measure was that early scientists could easily classify materials by whether they float on water (specific gravity less than 1.0) or whether they sink (specific gravity greater than 1.0).

With the specific gravity around 1.5, solid wood "substance", or lignocellulose as it is commonly called today, weighs around 1500 kg/m3 (93.6 lb/ft3), at theoretical most…no air, water, or other fluids in cell pores, which would decrease the weight of the wood per unit of volume. Wood also contains measurable quantities of organic "extractives" such as such as terpenes, resins, and polyphenols such as tannins, sugars, and oils. In addition, inorganic compounds such as silicates, carbonates, and phosphates appear in the wood as "infiltrates" and result in ash as the wood substance is decomposed. These extractives and infiltrates impregnate the lignocellulosic matrix and fill parts of the cavities of the wood. Ash, which makes up 0.5% to 2.0% of most woods, has a specific gravity of 1.6 to 2.8; the specific gravity of extractives varies depending on the substance. Together, the amount of ash and extractives in wood can vary from trace amounts to 30% and therefore affect the weight of wood differently according to species.

Thus far, we have been talking only of solid wood substance, which is not really wood as we know it. Wood of course, is comprised of cells, of which only the cell walls have the specific gravity stated above. Actual woods, the amazing composite of cell matrix in infinitely different shapes, sizes, and arrangements, much like a sponge made of lignocellulose, have much lower specific gravity than the theoretical maximum due to the amount of space in the matrix filled with air and water. And like a sponge, most woods float, and therefore have specific gravities less than 1.0; a few of the denser tropical hardwoods are actually heavier than water and sink. The most commonly referenced "heaviest wood", lignum vitae (Guaiacum officinale), has a specific gravity of 1.05 when green, which makes its weight about 1365 kg/m3, or 85 pounds per green cubic foot.

Now, green wood can have moisture content anywhere from 30% (denser woods) to over 200% (lighter woods). Let's talk about green wood in more detail.

First, that crazy moisture content calculation that confounds so many beginning wood science students. How, they wonder, can wood have more than 100% moisture?

It can't, of course. The moisture content calculation is simply a comparison of the mass of a sample of wood at any given moisture to its mass when "oven-dry", or when all the water has been removed from the sample. This is accomplished by drying the wood to a constant weight in a laboratory oven held at 101 to 105 degrees centigrade. The equation used for calculations is quite simple:

MC = (mgreen - mdry) / mdry (1)

So, to use a simple example, if a sample block of wood weighs 50 grams at original weighing, and 40 grams after being dried to 0% moisture content, then the moisture content of the original sample was (50-40)/40, or 25%. Now, suppose that original sample had weighed 100 grams. Then its original moisture content would have been (100-40)/40, or 150%.

We see in this example that an increase in moisture content results in the increased weight of green wood. This leads us also to the understanding that sapwood, with its higher moisture content in the field, often weighs more than heartwood. For softwood, this is practically always true. Hardwoods vary by species, and on average the moisture content in sapwood is only slightly higher. Table 4-1 of the 2010 Wood Handbook2 gives the heartwood and sapwood moisture contents of 40 North American hardwoods, and 28 North American softwoods. For the species in the table, the hardwood heartwood averages 81% moisture content, while the hardwood sapwood averaged 83%; the softwood heartwood, however, averages only 60%, while the softwood sapwood averaged 152%!

A similar situation exists between earlywood and latewood. Earlywood cells, formed in the fast-growing early weeks of growth when moisture movement is at its maximum, are necessarily larger with thinner cell walls to allow higher flow volume. As growth slows, the later cells formed take on a denser form with thicker cell walls and smaller cell lumina. Therefore, those species or specimens that exhibit wider bands of earlywood (or diffuse-porous species that exhibit no apparent latewood) will show more weight differential from green to dry than will those with significant bands of latewood.

The most technically correct way to calculate weight of wood gets somewhat tricky, because the specific gravity of woods changes with moisture content once the moisture content goes below 30%. 30% moisture content (plus or minus a couple of percentage points, based on the wood species and sample) is what we call the fiber saturation point of wood; above the fiber saturation point, the physical and mechanical properties of wood do not change as a function of moisture content. In other words, the specific gravity of wood does not change in wood that is above 30% moisture content. That is because the cellular structure of wood is "full" of what is called "bound water", the water chemically bonded to the wood.

The structure of the wood is fully expanded at this point, and any additional water that increases the moisture content is "free" water residing in the cell pores and lumina.

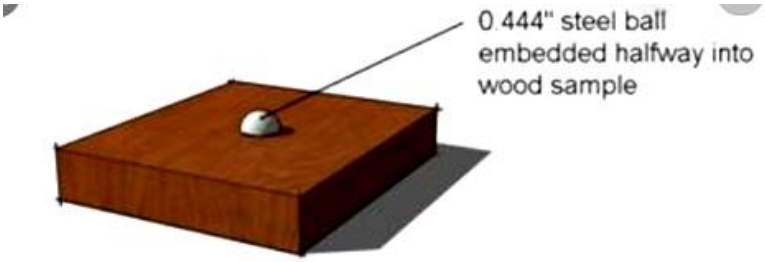
Once moisture content goes below 30%, however, all the free water has been released through evaporation, and the bound water begins to be chemically driven from the wood substance. As it does so, the wood cells begin to shrink, again, just as a sponge does as it dries out. And as it shrinks, the specific gravity of the wood gets higher, and the wood becomes stiffer as the chemical properties change. Most species increase in density anywhere from 10 to 20% as they dry from 30% down to oven dry, 0%. (This, by the way, is why wood checks and splits as it dries.) So another way of thinking about this is that the density of green wood (that above 30%) is different (less) than the density of the wood as stated in most references, which are usually given as specific gravity at 12% moisture content, for the purposes of aiding those who work with wood.

Hardness of the wood

It is the resistance which the wood offers to penetrate by another body and to wear and tear in general. It is a desirable in woods used for many purpose like oil mills, cart wheeld, tool handles, tent pegs , paving blocks, flooring, bearing blocks, axles.

The Janka **hardness test** is the **wood hardness** scale that measures the **hardness of wood**. The Janka **wood hardness** scale is determined by **measuring** the amount of force that is required to press a steel ball 11.28 mm (0.444 inches) in diameter into the **wood** to a depth of half the ball's diameter.

The hardness of wood varies with the direction of the wood grain. Testing on the surface of a plank, perpendicular to the grain, is said to be of "side hardness". Testing the cut surface of a stump is called a test of "end hardness". Side hardness may be further divided into "radial hardness" and "tangential hardness", although the differences are minor and often neglected.



Janka Hardness Test
Measures force needed
to embed ball

.Hardness depend on

1. Anatomical structure

The degree of cohesion of fibres and on the amount of ligneous matters contained in the tissues of the wood . Heart wood is harder than soft wood. Wavy fibre usually increases hardness.

2. Specific gravity

Generally hardness increases with specific gravity

3. Moisture content

Dry wood harder than green wood.

4. Presence of resinous material

The hardness of the wood is increased by the presence of resin.

5. soundness

Soft wood decay faster than hard wood by disintegrating and destroying the tissues.

Classification fo wood according to hardness

1.Extremely hard wood

Eg. Acacia Arabica

Hopea parviflora

Mesua ferrea

Dalbergia latifolia

Xylia xylocarpa

2.very hard

Eg, Dalbergia sissoo

Shorea robusta

Pterocarpus marsupium

3.Hard

Eg. Adina cordifolia

Albezzia labbek

Tectona grandis

4. Moderately soft

Mangifera indica

Calophyllum elatum

5. soft

Eg. Cedrus deodara

Melia dubia

Toona ciliate

6. Very soft

Eg, Boswellia serrata

Pinus roxburgii

7. Extremely soft

Eg. Bombax ceiba

Bombax insignis

Grain , Texture and Figure

The descriptive arrangement of the cells with regard to the axis of the tree is called grain. Grain may be straight, irregular. Diagonal, spiral, interlocked and curly or wavy.

Irregular grain occurs when fibres are at varying inclination to the vertical axis.; interlocked when fibres are inclined successively in opposite directon; diagonal when fibres are parallel to the longitudinal axis of the plank ; spiral when fibres fallow a spiral course; wavy when fibres fallow constantly changing direction.

Texture

Texture pertain to the relative size of the cells and their proportion to unit volume . Texture may be described as

fine (As in Adina cordifolia, Santalum album etc.)

Coarse (As in Shorea robusta, Tectona grandis, Albizzia labbek)

Even (As in Pinus excelsa)

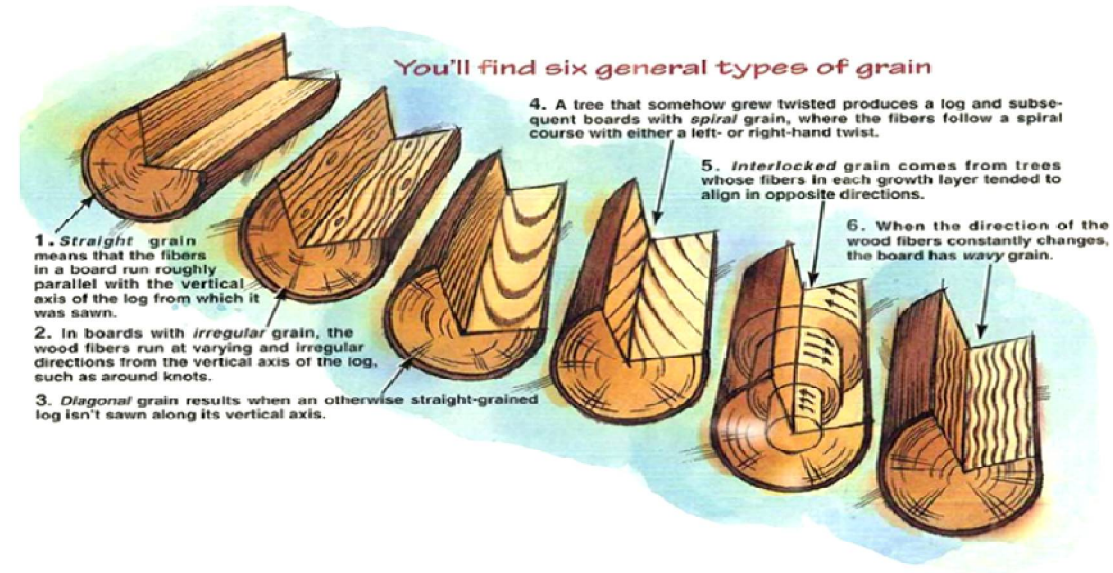
Uneven (As in Pinus longifolia)

Fine texture is associated with smaller sized cells; coarse with larger cells ; Fint texture wood take polish easily. Even texture wood less decorative than uneven texutured wood

Figure of the wood

Figure refers to distinctive pattern produced on longitudinal surfaces of timber as a result of arrangement of different tissues and direction of the grain.Figures may be attractive due to differences in the reflective property of different surfaces.

Wood grains are are the textured lines you can see on the surface of **wood**.



Woods with large **pores** that are easily visible to the naked eye are said to have an **open** grain. Those with smaller **pores**, to small to see clearly, have a closed grain. **Open**-grain **woods** appear coarser than closed-grain **woods** because the surface isn't as smooth.

A straight grain refers to wood grain that runs parallel to the axis of the tree. It does not weave or curl. Types of woods that have straight grain include **cherry**, hard **maple** and cedar. Woods with straight grain are much easier to work with and are generally stronger than other types of grain.

There are three **different types** of **wood grains** depending on the way to cut and slice the **wood**; flat **grain**(F), straight **grain**(S), and curly **grain**(C). Therefore, even within a same **wood** species, the **grain types** will vary depending on how it is cut and sliced.

Grain pattern or figure is created when we cut through the annual rings. Each of these yearly growth rings had a spring and summer growth, which varies with each species. Open **grain** woods have a very pronounced difference in the two growths, therefore they have a more pronounced grain pattern

Understanding Wood Grain

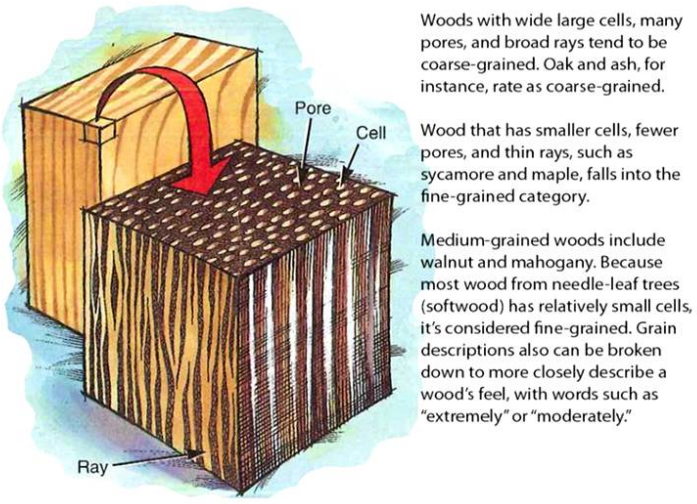
A craftsman selects a certain type of wood for a project because of a number of reasons. Grain is one. Yet that word has many meanings.

Technically, the word grain refers to the orientation of wood-cell fibers. That's quite different from figure, which describes the distinctive pattern that frequently results from various grain orientations. To understand this, it may help to think of the word direction following the word grain. All grain types except straight grain can be a blessing or a curse.

Because wood with anything other than straight grain may be sawn to produce sometimes exquisite figure, errant grain becomes a blessing. In structural applications, such as home construction, lumber (mostly softwood) with other than straight grain loses some strength. And hardwood boards without straight grain require extra care in machining to avoid tear out and other reactions.

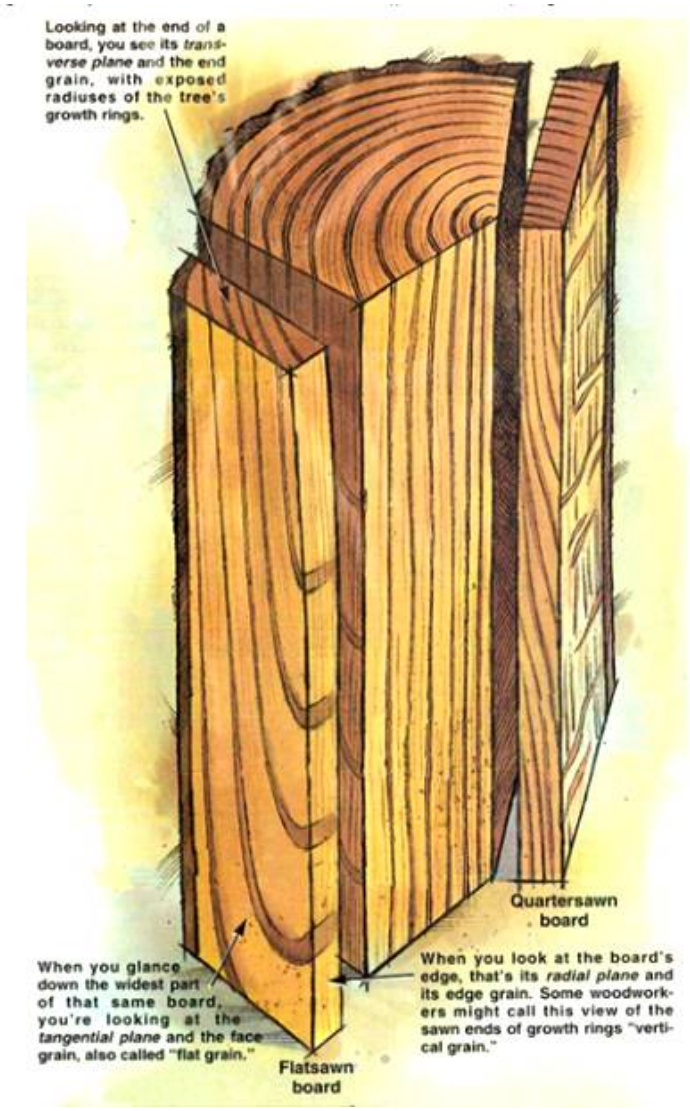
Grain Means texture, too

Texture means the relative size as well as the amount of variation in size of the wood cells. It's the cells and how they're arranged in bands called rays, and the size and distribution of pores, that make the difference between fine-textured wood and coarse-textured wood. Woodworkers, though, say "fine-grained" and "coarse-grained" rather than use the word texture to describe this characteristic of wood.



It's all in how you view a board

A flat sawn board, that is, one sawn from a log through and through without it being turned, has three surfaces or planes, as shown in the illustration (below). In true quarter sawn wood, the log must be sawn lengthwise into quarters. Then, each quarter log has to be sawn perpendicular to the growth rings. Although a quarter sawn boards have the same planes, its end-, face-, and edge-grain views will look different from a flat sawn board.


Looking at the end of a board, you see its *transverse plane* and the end grain, with exposed radiuses of the tree's growth rings.
Quartersawn board
When you look at the board's edge, that's its *radial plane* and its edge grain. Some woodworkers might call this view of the sawn ends of growth rings "vertical grain."
When you glance down the widest part of that same board, you're looking at the *tangential plane* and the face grain, also called "flat grain."
Flatsawn board

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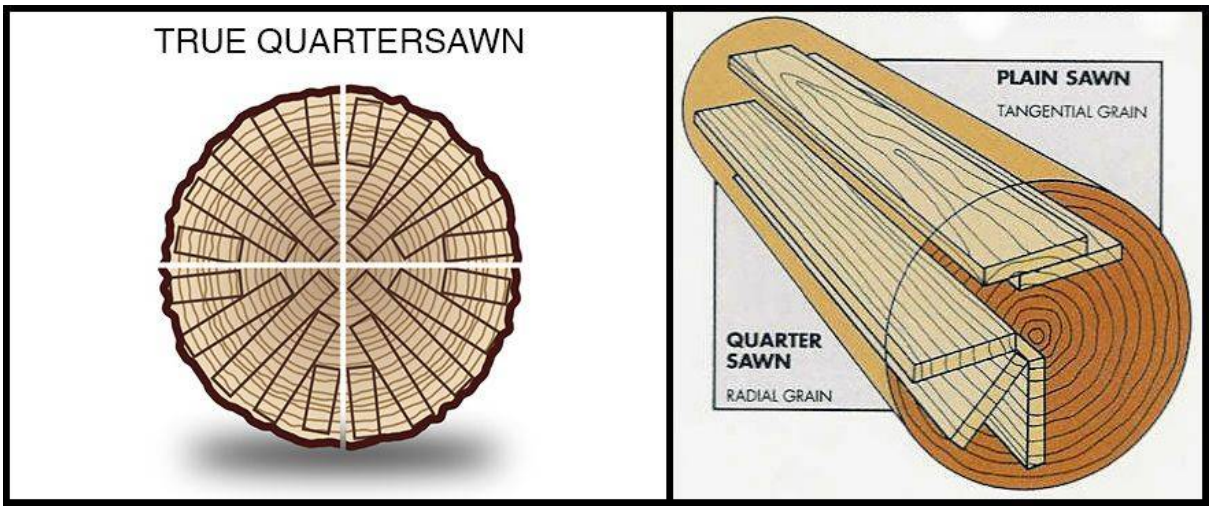
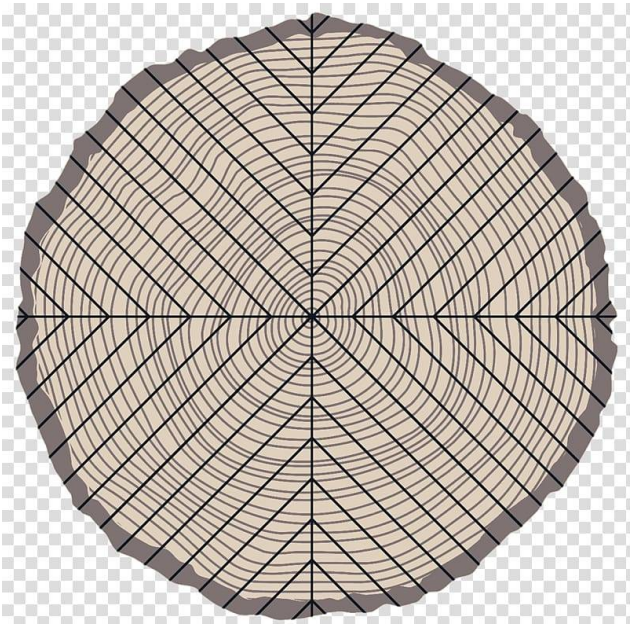

TRUE QUARTERSAWN
PLAIN SAWN
TANGENTIAL GRAIN
QUARTER SAWN
RADIAL GRAIN



2.4 Timber Identification

Wood has been of service to mankind through the ages. The most unique feature of wood, unlike other natural materials, is its high degree of structural variability. Even, two pieces of wood belonging to the same timber species may not be exactly alike. Even though the basic wood structure of the species is more or less similar; every fragment of it may show some difference. This attracts a unique fascination and attraction for this material. At the same time, it makes timber identification a tricky business. one has to learn to isolate those features that are characteristic of a certain timber, from others that many kinds of woods share.

Due to ignorance about the identity of timbers, usage of inferior and often unsuitable timber species such as Malaysian sal, and different species of acacias, eucalyptus and even conifers from temperate regions such as pines, have found their way into the timber market and have become popular for various end uses. However, the timber dealers, officials and the common man are left wondering as to the correct identification and utility of such species. Many instances of substitution of popular and traditional species by less costly and inferior species is happening in timber trade in the country, leading to litigations which have been reported from governmental as well as from other quarter

Identification keys

Keys based on the anatomical features serve a pivotal role in the identification of an unknown sample of wood. Since the anatomical features are relatively constant for each species they can be successfully employed in identification keys. The commonly used keys for wood identification are the dichotomous key, perforated card key and the computer aided identification key

1. ACACIA

Tree

Cross Cut

Flat Sawn

Trade Name:	Acacia
Vernacular Names:	Akasia (Indonesia); Australian Babul, Australian wattle, Acacia, Kasia (India); Darwin Black wattle, Tan wattle (Australia)
Botanical Name:	Acacia auriculiformis A. Cunn.ex Benth.
Family Name:	Leguminosae (Fabaceae)
Origin (Distribution:	An exotic. Native to Papua New Guinea (PNG), Australia and Solomon slands; introduced into many tropical countries as a fast growing species for pulp wood.
Tree:	A medium-sized tree reaching about 20m in height and 90cm in diameter. The species has become naturalized in many parts of India including Kerala.

General features

Acacia auriculiformis is moderately heavy wood. To identify the wood, check the following

:• Heartwood is dark brownish

• Wood is moderately heavy

• Parenchyma paratracheal and vasicentric.

• Rays fine, numerous and closely spaced.

• Vessels solitary and in radial multiples of two to three.

Colour - Heartwood is light brown to dark red; clearly demarcated from the yellowish white sapwood.

Weight - Moderately heavy (Air-dry specific gravity 0.60-0.75 with average values of 0.72)

Grain - Straight or wavy

Texture - FineStrength Strong

Drying and Shrinkage – Dries easily; shrinkage-radial (2.0%), tangential (4.0 %), volumetric (6.0 %)

.Durability - Moderately durable

Treatability - Moderately resistant

Working Properties - Planing-easy; boring-easy; turning-easy; nailing-satisfactory; finish-good

T S (x100)

TLS (x10)

Gross features -Growth rings fairly distinct. Diffuse porous wood.

Vessels solitary and in radial multiples of two to three, large to medium sized and moderately numerous (15-24/mm2). Soft tissue forms sheaths around vessels.

Rays fine, numerous and closely spaced; one to three cell wide, homogeneous, wholly made up of procumbent cells.

Parenchyma paratracheal and vasicentric.

2.AYANI/ANJILI

Trade Name	Ayani
Vernacular Names	Anjili, Ayani, Ansfeni (Mal.), Hebbalesu, Hessua,Hessuain (Kan.), Dinipilla (Tam.), Pejata (Tel.)
Botanical Name	Artocarpus hirsutus Lamk
Family Name	Moraceae
Origin (Distribution	West coast tropical evergreen, west coast semi-evergreen and southern secondary moist mixed deciduous forests;

	commonly seen in Western Ghats in Karnataka and Kerala and in South Maharashtra
Tree	A lofty evergreen tree, large to very large, 25-45m in height with a clear bole of 10-20m and 130cm in diameter. Bark dark brown, smooth

Tree

Cross cut

Flat sawn

General features

Artocarpus hirsutus Lamk (Ayani) is a moderately hard and moderately heavy wood. To identify the wood, check the following:

• Heartwood is golden yellow to yellowish brown

• Parenchyma: paratracheal- vasicentric to aliform

• Rays moderately broad to fine, fairly wide spaced

• Vessels very large to large, few, solitary or in radial multiples of two or three, often filled with tyloses or white chalky deposits

• Resembles Jack wood in many respects, but differs in its yellowish-brown colour and lustrous appearance

Colour Heartwood - golden yellow to yellowish brown, lustrous when first exposed; darkens on exposure to dark yellowish brown with darker streaks. Sapwood is greyish or yellowish white.

Weight - Moderately hard and moderately heavy (595 kg/m3 at 12% m.c.)

Grain - Straight to interlocked

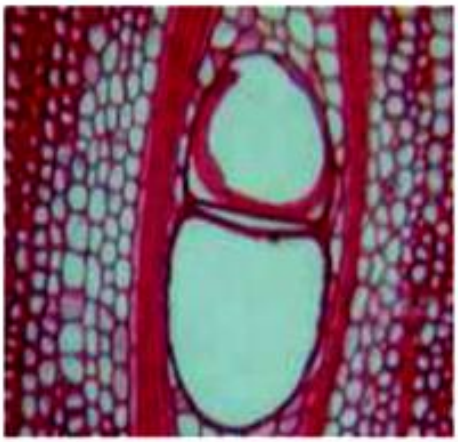
Texture - Medium to coarse

Strength - Strong

Drying and Shrinkage - Air and kiln-seasoning offer no difficulty. Shrinkage green to oven dry- radial (3.4%), tangential (5.3%). The converted material stacked in open piles with good circulation of air through the stock, gives best results. Kiln-drying schedule IV is recommendedDurabilityDurable. - Moderately refractory

Treatability - The heartwood is refractory to treatment.

Working Properties - Easy to saw and machine when green; turns well to a good shining surface; takes lasting polish.



TS

TLS

Gross features Growth rings indistinct to distinct, when distinct demarcated by slightly denser and darker coloured latewood fibrous tissues. A diffuse porous wood.
Vessels very large to large few solitary or in radial multiples of two or three, oval to round in outlines, often filled with tyloses or white chalky deposits
.Parenchyma paratracheal - vasicentric to medium to aliform, forming light coloured haloes or eye-lets round the vessels often extending sideways joining similar extensions.
Rays moderately broad to fine, fairly wide spaced and uniformly distributed, forming distinct or inconspicuous flecks on the radial surface

3. BABUL

Trade Name	Babul
Vernacular Names	Babul (India), Gabdi (Cameroon), Mgunga (East Africa), Babla (Bangali), Bamura (Gond.), Baval, Bawal (Guj.), Babul, Babur (Hind.), Fati, Gobli, Jali, Karrijali, Meshwal (Kan.), Karuvelam

	(Mal.), Kikar (Punj.), Karuvai, Karuvelam (Tam.), Nella tuma (Tel.)
Botanical Name	Acacia nilotica (Linn.) Wild. ex Del. Syn. Acacia arabica Auct. non (Lamk.) Willd.
Family Name	Leguminosae (Fabaceae
Origin (Distribution	India (Gujarat, Rajasthan, Maharashtra, Madhya Pradesh) and Africa. Grows naturally in the deciduous forests of Peninsular India. In Kerala, occasionally grown in dry areas.
Tree	Small sized evergreen tree reaches a height of 10 m and is about 30 cm in diameter with short thick cylindrical trunk and a spreading crown. Bark is dark brown or black, rough, with deep narrow longitudinal fissures running spirally.

Tree

Cross cut

Flat sawn

General features

The heart wood of Acacia nilotica (Babul) is pinkish brown to reddish brown and is lustrous. To identify the wood, check the following:

• Pinkish brown to reddish brown and lustrous heart wood.
• Wood is hard and heavy
• Growth rings are indistinct
• Prominent paratracheal (vasicentric) parenchyma• Vessels are small and few and filled with dark brown gummy deposits

Colour - Heartwood pinkish brown to reddish brown, lustrous; Sapwood wide, white to pale yellow.Heart wood is sharply demarcated from the sapwood.
Weight - Hard and heavy (800 kg/m3 at 12% m. c)
Grain - Straight to interlocked
Texture - Medium to coarse
Strength - Strong
Drying and Shrinkage - Dries rather slowly without degrade; Shrinkage- radial (2.6%), tangential (6.0%), volumetric (8.6%). It requires care in seasoning

as it is liable to develop surface cracking and end- splitting unless protected against rapid drying.

Durability - Very durable

Treatability - Resistant

Working - PropertiesPlaning rather easy; Boring-easy; Turning-easy; Nailing-good but pre- boring necessary; Finish-good

T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.

Growth rings are indistinct.

Vessels medium to small, few to moderately few, mostly solitary or in radial multiples of two, three or more, occasionally in clusters; filled with dark brown gummy deposits. Soft tissues are visible to the eye forming thick sheaths or 'halos' round the pores.

Parenchyma paratracheal- va-sicentric, fine lines delimiting growth rings.

Rays moderately broad to fine, rather widely and irregularly spaced.

4. BENTEAK

Trade Name	Benteak
Vernacular Names	Arale, bendeku, bentik, nandi (Kan.), Ventek (Mal.), Nana (Mar.), Vivella, Venteak, Venteku (Tam.), Chennangi, Ventaku (Tel.)

Botanical Name	Lagerstroemia microcarpa Wight.Syn. Lagerstroemia lanceolata Wall.exClarke, Lager-stroemia thomsonii Koehne
Family Name	Lythraceae
Origin (Distribution	West coast semi evergreen, moist teak bearing and southern moist mixed decid-uous forests. It is common throughout the Western Ghats from Bombay south-wards through Karnataka extending to Travancore and the Nilgiris.
Tree	Large about 20-30 m in height and up to 110 cm in diameter, 2.4-3 m in girth with a clear bole of 12-15 m.Bark white or yellowish- grey, smooth, exfoliating in large pa-pery flakes.

Tree

Flat Sawn

Cross Cut

General features

Lagerstroemia microcarpa Wight. (Benteak) is a moderately heavy wood. To identify the wood, check the following:

• Heartwood reddish brown to walnut brown.

• Wood is moderately heavy

• Parenchyma paratracheal- predominantly aliform-confluent.

• Rays fine, numerous and closely spaced.

• Vessels large in early wood, medium to small in late wood, moderately numerous (4-6/mm2), solitary or in radial multiples of 2 or 3, usually filled with abundant tyloses.

Colour - Sapwood grey or pink, heartwood reddish brown to walnut brown, darkening on exposure.

Weight - Moderately hard to moderately heavy, slightly to fairly lustrous, 640 kg/m3 at 12% m.c.
Air dry specific gravity 0.59- 0.76

Grain - Straight to somewhat interlocked.

Texture - Medium

Strength – Strong

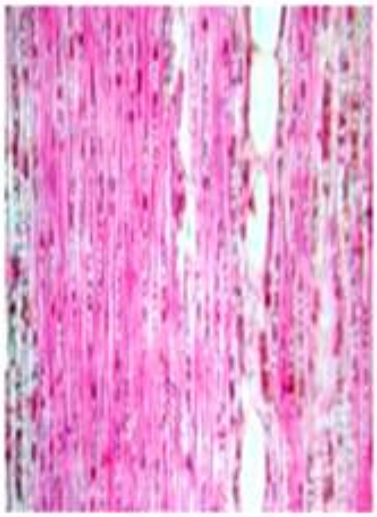
Drying and Shrinkage - Air-seasoning is difficult. Kiln-seasoning recommended.

Durability - Durable

Treatability - Heartwood very refractory to treatment

Working Properties - Sawing and machining satisfactory, finishes to a smooth surface and takes good polish

T S (x100)



TLS (x100)

Gross features

Wood is semi-ring-porous to ring porous.

Growth rings distinct, demarcated by large early wood vessels and fine to fairly broad parenchyma bands.

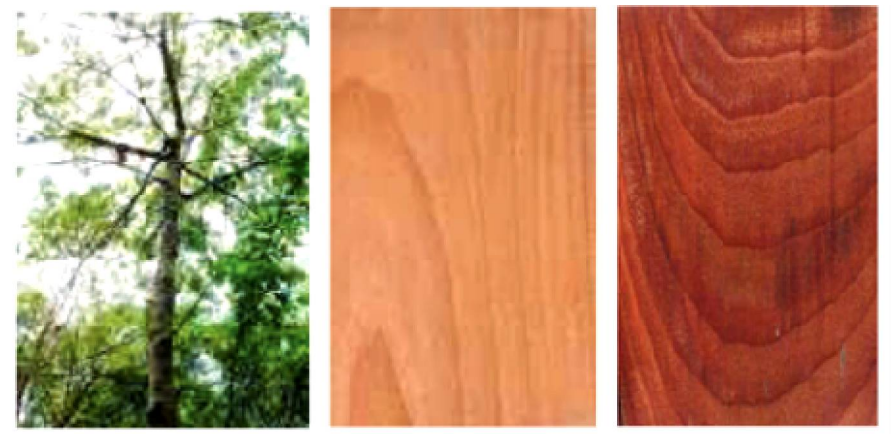
Vessels large in early wood, medium to small in late wood, moderately numer-ous (4-6/mm^2), solitary or in radial multiples of 2 or 3, round to oval, vessel lines distinct, usually filled with abundant tyloses, clearly visible to the unaided eye. Soft tissue forms eyelets around vessels, often join together to form bands.

Parenchyma paratracheal- predominantly aliform-confluent, abundant, mainly as 'haloes' or eyelets round the vessel or vessel groups

Rays fine, numerous and closely spaced.

5. DHAMAN

Trade Name	Dhaman
Vernacular Names	Damnak (Bhil.); Dhamani, daman (Mar.); Dadsal, butale, thadsal, batala (Kan.); Dhamana (Guj.); Dhaman, baringa (C. P); Khosla, kasul (Gondi); Charachi, jana, tharra, (Tel.); Unu, chadachchi, charachi, unam (Tam.); Pharsa, phalsa, dhamin (U. P); Pharsia (Kumaon); Dhaman, dhamin, phalsa, pharsa , (Hind.); Chadache, chadicha, sadachu (Mal.); Bhangia, dhamani, dhamono, dhamuro (or.)
Botanical Name	Grewia tiliifolia Vahl
Family Name	Tiliaceae
Origin (Distribution	Southern moist mixed deciduous, teak bearing and semi-evergreen forest. It is a common tree of Himachal Pradesh, Bihar, West Bengal, Assam, orissa, Rajasthan, Gujarat, Maharash-tra, Goa, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala; also in Sri Lanka
Tree	Medium sized tree with 20 m height, 60 cm diameter and 1.5 m in girth with a clear bole of 4-6 m.; bark pale grey in young trees, dark or blackish brown in old trees, fibrous, rough, peels off in thin flakes.



General features

Grewia tiliifolia (Dhaman) is a moderately heavy wood. To identify the wood, check the following:

• Heart wood reddish brown to brown with black or dark streaks

.• Wood is moderately hard to hard, moderately heavy to heavy

• Parenchyma paratracheal, abundant, vasicentric or aliform.

• Rays fine to broad and close.

• Vessels punctuate with the naked eye, solitary and in radial multiples of two to three; medium-sized; few to moderately numerous (6-10 per mm2), filled with tyloses or chalky deposits.

Colour - Sapwood yellowish white or pale yellowish, turning brownish grey with age. Heartwood reddish brown to brown with black or dark streaks.
Weight - Moderately hard to hard, moderately heavy to heavy (785 kg m3 at 12 % m. c)

Grain - Straight

Texture - Medium to coarse

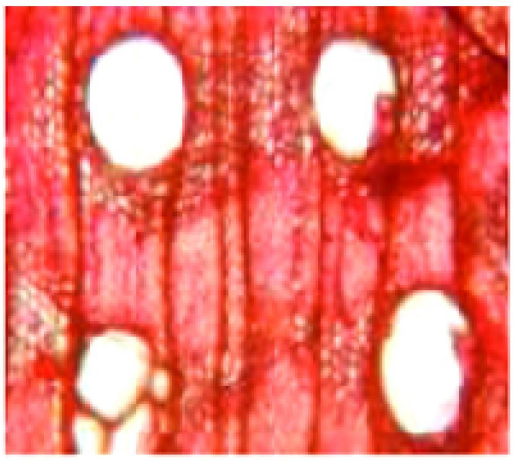
Strength - Strong

Drying and Shrinkage: - Moderately refractory, liable to surface cracking and end-splitting; conversion soon after felling and stacking under cover recommended.
Shrinkage: Radial 4.1%; tangential 7.9 %; volumetric 14.5%.

Durability - A very durable timber both in the open and under cover.

Treatability - Heartwood refractory to treatment.

Working Properties: - Easy to saw and worked up very easily, both on machines and by hand; can be brought to a smooth finish and takes good polish



TS

TLS

Gross features
Growth rings distinct, demarcated by dense, darker latewood fibers. Diffuse porous to semi-ring-porous wood.
Vessels punctuate with the naked eye, solitary and in radial multiples of two to three; medium to small-sized; few to moderately numerous (6-10 per mm2), filled with tyloses or chalky

deposits. Soft tissue forming halos around vessels and also banded; not readily visible, even with a hand lens.

Rays fine to broad, close, 5-11 mm; few and spaced. Ripple marks occa-sionally faintly visible.

Parenchyma paratracheal, abundant, vasicentric or aliform, visible with a hand lens. Apotracheal parenchyma diffuse and also in tangential lines

6. EBONY

Trade Name	Ebony
Vernacular Names	Balemara (Kan.), Karimaram (Mal.), Kendhu (or.) Nalluti (Tel.)
Botanical Name	Diospyros ebenum Koenig ex Retz
Family Name	Ebenaceae
Origin (Distribution	Sporadic in West coast semi-evergreen forests. It is also found in the forests of Deccan extending north to the Cudappah and Kurnool districts of Andhra Pradesh, Tamil Nadu and in South orissa, South Coimbatore, Tirunelvely and Srilanka
Tree	Small to medium, occasionally attains a height of 20 m, girth of 2.5 m and about40 cm in diameter. Bark dark grey with longitudinal fissures

Tree Flat Sawn Cross Cut

General features

Diospyros ebenum Koenig. (Ebony) is very hard and very heavy. To identify the wood, check the following:

• Heartwood is uniform jet black or black brown sometimes with streaks

.• Vessels small, few to moderately few, solitary or in radial multiple of two or three; filled with brownish-black or black gum.

• Parenchyma apotracheal-fine undulating tangential lines

.• Rays very fine and closely spaced

Colour-:Heartwood small, uniform jet black or black brown sometimes with streaks; clearly demarcated from the pale red brown or light yellow-ish grey sapwood.

Weight:-Very hard and very heavy; air dry specific gravity 0.96-1.12 with an average value of 1 (1150 kg/m3 at 12% m.c).

Grain:-Straight to slightly interlocked or somewhat curly.

Texture -Fine

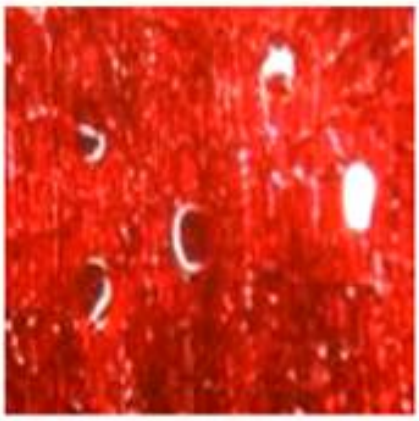
Strength -Very strong.

Drying and Shrinkage:- Dries fairly rapidly. Shrinkage radial (5.5%), tangential (6.5%), volumetric (12%). It is difficult to season as it has a tendency to develop splitting and surface-cracking and requires protection against rapid drying.

Durability - durable

Treatability - Extremely resistant. Refractory to treatment. The light coloured portion Of the wood can be treated satisfac-torily with preservatives.

Working - Properties:Planing-slightly difficult; Boring-easy; Turning-easy; Nailing-good; but pre- boring necessary; Finish-good



T S (x100)

TLS (x10)

Gross features

Wood is diffuse porous.

Growth rings are indistinct.Vessels small, few to moderately few, moderately numer-ous (6-15 per mm2) solitary or in radial multiples of two or three, evenly distributed; filled with brownish-black or black gummy deposits in the heartwood.

Vessel lines indistinct to inconspicuous.

Parenchyma apotracheal-fine undulating tangential lines, diffuse to diffuse-in-aggregates at places forming a reticu-lum with the rays.

Rays very fine closely and evenly spaced.

7.GAMARI/ KUMBIL

Trade Name	Gamari, Kumbil
Vernacular Names	Gamar (Bangladesh), Gamari, Gumhar, Kumbil, Gomari, Gambar, Shewan, Kumil (India).Yemane (Myanmar, Malaysia, Philippines), Gomari (Asm.),Shewan (Guj.), Gambhar (Hind.),Kulimavu (Kan.), Kumala (Tam.), Gummadi (Tel.)
Botanical Name	Gmelina arborea Roxb.
Family Name	Verbenaceae
Origin (Distribution	Native to India, Sri Lanka, Myanmar, Southern China, Laos, Cambodia, Vietnam, Indonesia and introduced to many tropical countries as a fast growing tree species. Sporadic in moist teak bearing and southern secondary moist mixed deciduous forest.
Tree	Medium, 15-20 m in height, 40-65cm in diameter and a girth of 1.5-2 m. Bark whitish grey, corky, warty, lenticellate ex- foliating in regular thin flakes.

Tree

Flat Sawn

Cross Cut

General features

Gmelina arborea Roxb. (Gamari, Kumbil) is soft to moderately hard and light to moderately heavy. To identify the wood, check the following:

• Wood is creamy white to pale yellowish-grey turning to yellowish- brown on exposure.

• Parenchyma mostly paratracheal-vasicentric and also in terminal bands delimiting growth rings.

• Rays broad to moderately broad, distinct to the eye, few, rather widely spaced and uniformly distributed.

• Vessels large to medium, distinct to fairly distinct to the eye, rather uneven-ly distributed, few to moderately numerous, mostly solitary and in short radial multiples of 2 or 3, rounded in outline; tyloses abundant

Colour: -Heartwood and sapwood not distinct in color; creamy white to pale yellowish- grey or buff turning to yellowish-brown on exposure, moderately lustrous.

Weight: -Soft to moderately hard and light to moderately heavy

Grain: -Straight to interlocked or slightly wavy

Texture - Medium to coarse

Strength - Moderately strong

Drying and Shrinkage:- Easy to air-season; kiln-seasoning offers no difficulty. Dries fairly rapidly;

shrinkage-radial (2.4%), tangential (4.9%), volumetric (8.8%).

Durability - Very durable

Treatability - Resistant; heartwood is very refractory to treatment.

Working Properties: - Planing-easy; Boring-easy; Turning-easy; Nailing-easy; Fin-ish-good. Easy to saw, works to a fairly smooth finish and takes good polish.Usually very uniform in colour and except for occasional roe-mottling which gives the wood a silvery sheen. Being very steady after seasoning, it is considered as a first class work-shop wood.

T S (x100)

TLS (x10)

Gross features

Wood is diffuse-porous to semi-ring- porous. Growth rings scarcely distinct and delimited by comparatively larger early wood vessels and fine lines of parenchyma.

Vessels large to medium, distinct to fairly distinct to the eye, rather unevenly distributed, few to moderately numerous, mostly solitary and in short radial multiples of 2 or 3, rounded in outline; tyloses abundant.

Parenchyma mostly paratracheal-vasicentric and also in terminal bands delimiting growth rings.

Rays broad to moderately broad, distinct to the eye, few, rather widely spaced and uniformly distributed.

8. HALDU

Trade Name	Haldu
Vernacular Names	Manjakadambu, Veembu (Mal), Lampatia, Tarak chapa (Asm.), Keli- kadam (Beng.), Haladwan, Holdarvo (Guj.), Haldu, Hardu (Hind.), Avanu, Kadambe (Kan.), Manja-kadambai (Tam.), Bandaru, Dodaga (Te l.)
Botanical Name	Adina cordifolia (Roxb). Hook.f.ex. Brand.(Syn. Haldina cordifolia)

Family Name	Rubiaceae
Origin (Distribution	Southern moist mixed deciduous forests throughout India, except in arid regions of Rajasthan, moist teak bearing forests and West-coast semi ever green forests. It also occurs in the sub-Himalayan tract from Jamuna eastwards upto Bhutan and is com-mon throughout central, western and southern India, Burma and Sri Lanka.
Tree	Medium to very large tree, 15-35 m in height, 2-3.5 in girth with a clear bole of9-12 and upto 110 cm in diameter; often unevenly fluted and buttressed at the base. Bark grey, soft, thick, exfoliating in small irregular flakes, blaze light red inside with white streaks.

General features

Adina cordifolia (haldu) has heart wood that is deep yellow. To identify the wood, check the following:

• Heart wood is deep yellow turning reddish or brownish on exposure.

• Wood is light to moderately heavy and has a fine texture

• Parenchyma is sparse and indistinct to the naked eye

• Rays are fine, numerous and closely spaced

• Vessels are small, solitary and in radial multiples of two to three

Colour: - Sapwood pale yellowish or yellowish white. Heart wood is deep yel-low turning reddish or brownish on exposure.

Weight:- Moderately hard and light to moderately heavy (695 kg/m3 at 12% m.c).

Grain: - Fairly straight to somewhat interlocked.

Texture - Fine textured

Strength - Moderately strong

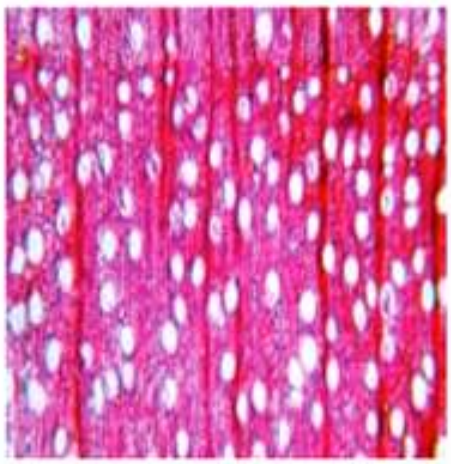
Drying and Shrinkage:- Green conversion and open stacking under cover recommended. Kiln- seasoning offers no difficulty and brightness of the colour is retained better than the air-seasoned stock. Shrinkage- radial (3.4%), tangential (6.8%).

DurabilityNon - durable

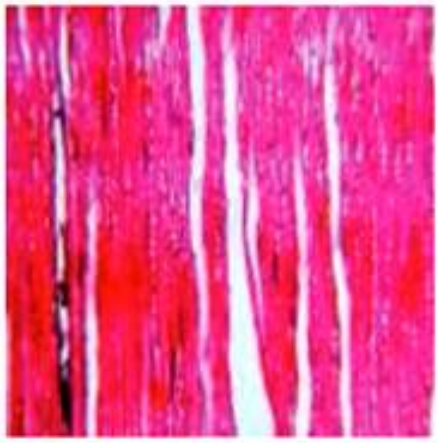
Treatability - Easily treatable, but the uses to which the timber is currently put, do not

necessitate preservative treat-ment.

Working Properties: - Sawing not difficult, machining satisfactory, works fairly easy giving good finish.



T S (x100)



TLS (x10)

Gross features

Wood is diffuse porous. Growth rings indistinct.

Vessels solitary and in radial multiples of two to three, small to very small sized, numerous to very numerous (25-45 per mm2), evenly distributed, oval in outline, open, vessel lines indistinct, not clearly visible to the naked eye. Soft tissue indistinct to the eye, but visible as bands under a hand lens.

Parenchyma extremely sparse paratacheal-scanty; apotracheal, relatively abundant, diffuse and diffuse in aggregate.

Rays fine, numerous and closely spaced.

9.Jack wood

Trade Name	Jack wood
Vernacular Names	Plavu, Pilavu, Kathal (Mal), Kanthol (Beng.), Alasu, Halasu (Kan.), Phanas (Mar), Pila, Pilapalam (Tam.), Panasa (Tel.)
Botanical Name	Artocarpusheterophyllus Lamk.Syn. Artocarpus integrifolia (Linn.f)
Family Name	Moraceae
Origin (Distribution	West coast tropical evergreen and southern hill-top tropical evergreen forests and Western Ghats commonly in Deccan, warmer parts of the countries like West Bengal, Bihar and Manipur; widely cultivated
Tree	A medium to large, evergreen tree reaching 18-25 m in height and 120 cm in diam-eter. Bark thick and blackish, mottled with black and green, rough with warty excres-cences.

Tree

Flat Sawn

Cross Cut

General features

Artocarpus heterophyllus (jack wood) is a moderately hard and moderately heavy wood. To identify the wood, check the following:

• Heartwood which is distinguishable from sap wood is yellow to yellowish brown and lustrous

• Parenchyma is paratracheal, forming halos around vessels

• Rays are clearly visible to the naked eye

• Vessels solitary and in radial multiples of two to three; large to medium-sized and often filled with tyloses and white chalky deposits

Colour -Heartwood yellow to yellowish brown or pinkish brown with darker streaks, lustrous when first exposed. Sapwood is greyish or pale yellow.

Weight - Moderately hard and moderately heavy. 555 kg/m3 at 12% m.c.

Grain - Straight to interlocked

Texture - Coarse to medium

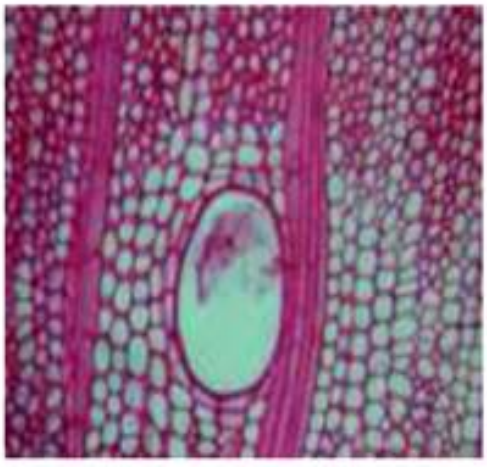
Strength - Strong

Drying and Shrinkage:- Seasons well when open stacked after conversion without trouble or degrade. The converted mate-rial stacked in open piles with good circulation of air through the stock, gives best results. Kiln-drying schedule III is recommended.

Durability - Very durable

Treatability - The heartwood is refractory to treatment.

Working Properties - Easy to saw and work, can be brought to a smooth finish and takes good polish.



T S (x100)

TLS (x100)

Gross features

Growth rings indistinct to distinct, when distinct, demar-cated by slightly denser and darker coloured latewood fibrous tissues. Wood diffuse porous.

Vessels solitary and in radial multiples of two to three; large to medium-sized, clearly visible with a hand lens; few to moderately numer-ous (2-5 per mm2), oval to round in outlines, often filled with white chalky deposits or tyloses. Soft tissue forming light coloured halos around vessels often extending sideways joining similar extensions and sometimes forming bands.

Parenchyma paratracheal-vassicentric to aliform.

Rays moderately broad to fine, few and widely spaced and uniformly distributed, forming inconspicuous flecks on the radial surface; clearly visible to the unaided eye.

10. KADAM

Trade Name	Kadam
Vernacular Names	Kadam (Hin.), Cadamb, Attu –teak, Kodavara, Chakka, Kadambam (Mal.), Roghu (Asm.), Kadam (Beng.), Kadamb, Karam (Hind.), Bale (Kan.), Kadamba, Nhyu (Mar.), Kadambo (or.), Vellei-Kadamba, Kola-aiyila (Ta m.), Kadambe (Te l.
Botanical Name	Anthocephalus chinensis (Lamk.) A.Rich. ex Walp. [Syn. Anthocephalus cadamba (Roxb.) Miq.
Family Name	Rubiaceae
Origin (Distribution	West coast semi-evergreen forests. It occurs in the sub-Himalayan tract from Nepal eastwards in the lower hills of Darjeeling, Assam, Bihar, orissa, Eastern Ghats, Anda-mans and Burma. It is a tree of moist warm regions, deciduous and evergreen forests.
Tree	Medium to large tree with a straight cylindrical bole and horizontal branches,15-25 m in height and 1.5-2.5 m in girth with a clear bole of 9 m and about 60 cm in diameter. Bark dark grey with longitudinal fissures; peels off in thin scales

Tree Flat Sawn Cross Cut

General features

Wood of Anthocephalus chinensis is white with a yellowish tinge and heartwood that is not distinguishable from sap wood. To identify the wood, check the following

• Wood is light to moderately heavy

• Growth rings are fairly distinguishable

• Parenchyma is scanty

• Rays are coarse-storied

• Vessels are large to very small and moderately numerous to numerous, mostly solitary or in radial multiples of 2, 3 or 4.

Colour: - Heart wood and sapwood are not distinct. White with yellowish tinge to cream white or yellowish grey.

Weight:- Light to moderately heavy, 385 to 640 kg/m3 at 12 % m. C

Grain: - Straight

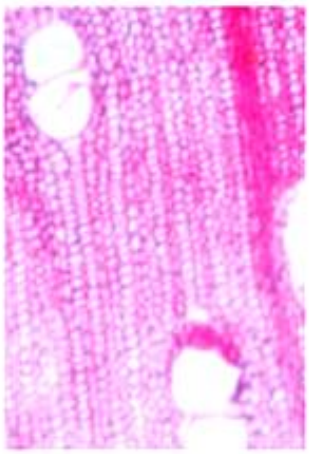
Texture - Medium to fine

Drying and Shrinkage: - It can be seasoned easily without any cracking and warping. Conversion soon after felling and stacking between stickers under cover recommended.

Durability - Perishable.

Treatability - Heartwood easily treatable with preservatives.

Working Properties: - Sawing and working are not difficult. It can be peeled readily on a rotary cutter.



T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.Growth rings fairly distinct, but not conspicuous.

Vessels large to very small, moderately numerous to nu-merous (4-15 per mm2), mostly solitary or in radial multiples of 2, 3 or 4,oval in outline, open,vessel lines distinct

Parenchyma paratracheal-scanty; apotracheal diffuse to diffuse-in- aggregates, tending to form a net like structure with rays.

Rays very fine, closely spaced.

11. KANJU

Trade Name	Kanju, Indian elm
Vernacular Names	Anjan (Beng.); Chirol, Karanji, Papri (Hind.); Aval (Mal.); Papara (Mar.); Thapsi (Kan.); Chilbil (or.); Ayili (Ta m.)
Botanical Name	Holoptelea integrifolia (Roxb.) Planch.
Family Name	Ulmaceae
Origin (Distribution	West coast semi-evergreen and occasionally in moist teak bearing forest.
Tree	Medium to large-sized, 15-25 m in height and 80 cm in diameter; bark whitish-grey, thin, with longitudinal furrows and exfoliating in irregular flakes

Tree Flat Sawn Cross Cut

General features

Holoptelea integrifolia (Kanju) is a moderately heavy wood. To identify the wood, check the following:

• Heartwood and sapwood are not distinct. Wood light yellow or yellowish grey• Wood is moderately hard and moderately heavy.

• Parenchyma paratracheal, aliform and winged type

• Rays fine to moderately broad, closely spaced and numerous

• Vessels solitary and in radial multiples of two to three, medium- sized

Colour: - Heartwood and sapwood are not distinct.Wood light yellow or yel-lowish grey, darkening on exposure; somewhat lustrous.

Weight: - Moderately hard and moderately heavy (595-600 kg/m3 at 12 % m.c)

Grain: - Shallowly interlocked

Texture - Medium coarse

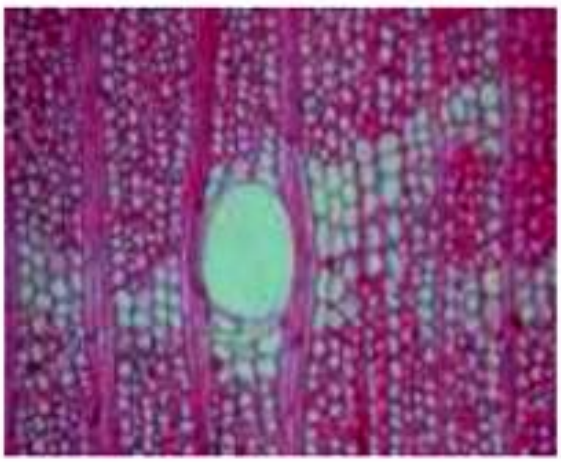
Strength – Strong

Drying and Shrinkage: - Seasons well. Kiln-seasoning offers no difficulty.

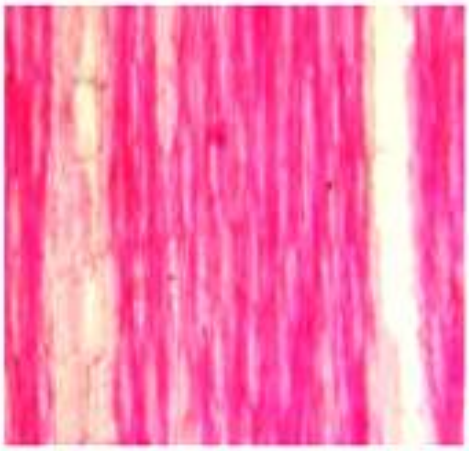
DurabilityNon - durable

Treatability - Heartwood treatable but complete penetration not always obtained.

Working Properties :- Easy to saw and work, turns to a fine smooth surface and takes good polish. Turning-easy, finish-good.



T S (x100)



TLS (x100)

Gross features

Growth rings distinct. Diffuse porous wood.

Vessels solitary and in radial multiples of two to three, medium-sized, mod-erately numerous (5-8 per mm2), filled with white chalky deposits. Soft tissue forms eyelet shaped patches around vessels.

Rays fine to moderately broad, closely spaced and numerous. Ripple marks present.

Parenchyma paratrache-al, aliform and winged type; also confluent bands of one to three cell widths present.

12. MAHOGANY, AMERICAN

Trade Name	Mahogany
Vernacular Names	Honduras mahogany, Guatemala mahogany, Brazilian mahogany, Mogno (Brazil), Zopilote, Chiculte (Mexico)
Botanical Name	Swietenia macrophylla King
Family Name	Meliaceae
Origin (Distribution	Native to Central and South America, particularly Mexico and Honduras, and intro-duced to many tropical countries including India. It is widely cultivated as an avenue tree.
Tree	A medium sized tree reaching a height of 12-18 m and a diameter of 80-130 cm

Tree

Flat Sawn

Cross Cut

General features

Swietenia macrophylla (bigleaf mahogany) is a hardwood. To identify the wood, check the following:

• Heartwood is reddish brown

• Wood is moderately hard and heavy

• Prominent marginal parenchyma

• Rays are coarse-storied• Vessels are large (easily visible with naked eye), often in multiples of 2/3. It is a CITES Appendix II timber species.

Colour:- Heartwood colour varies from light reddish or yellowish brown to dark reddish brown, lustrous. Sapwood yellowish white to pale brownish gray.

Weight:- Moderately heavy 650 kg/m3 at 12% m. C

Grain:- Straight to interlocked. Flat-sawn surface produce prominent growth ring figure.

Texture - Medium to coarse

Strength - Strong

Drying and Shrinkage:- Dries fairly rapidly without degrade; Shrinkage- radial (2%), tangential (3%), volumetric (5%)

Durability - Moderately durable

Treatability: - Extremely resistant

Working Properties -Planing-easy; boring-easy; Turning- easy; Nailing-satisfactory, but pre-boring necessary; Finish-good

T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.Growth rings distinct.

Vessels solitary and in radial multiples of two to three, medium-sized, moderately numerous (10-15 per mm2). Soft tissue banded and forms incomplete sheaths around vessels. Pores usually stained or discoloured, darker, are large and evenly spread through the wood.

Rays fine to moderately broad, few and widely spaced. Rays can be seen clearly on radial-cut surfaces as smooth plates which reflect the light.

13. MANGIUM

Trade Name	Mangium
Vernacular Names	Brown salwood, Black wattle, Hickory wattle (Aus.); Mangge hutan, Tongke hutan (Ceram), Nak (Maluku), Laj (Aru), Jerri (Irianjaya) (Indonesia); Arr (Papua New Guinea); Mangium, Kayu SAFODA (Malaysia); Kra thin tepa (Thailand)
Botanical Name	Acacia mangium Willd.
Family Name	Leguminosae (Fabaceae)
Origin (Distribution	An exotic, native to Australia, Papua New Guinea and Indonesia; widely cultivated in different parts of Kerala.
Tree	A medium-sized tree, reaching a height of 10-18 m and a diameter of 60-70 cm

General features

Acacia mangium is moderately heavy wood. To identify the wood, check the fol-lowing:

• Heartwood is yellowish brown.

• Wood is moderately hard and moderately heavy.

• Parenchyma paratracheal and vasicentric

.• Rays fine, numerous and closely spaced.

• Vessels solitary and in radial multiples of two to three.

Colour: - Heartwood is yellowish brown and sapwood is creamy white in colour.

Weight: - Moderately hard and moderately heavy (70 kg/m3 at 12 % m. C

Grain: - Straight to interlocked

Texture - Medium to fine

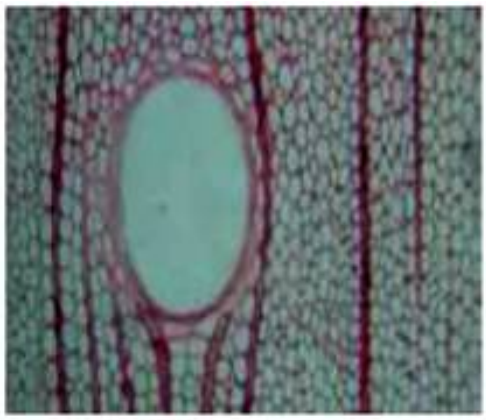
Strength – Strong

Drying and Shrinkage:- Dries slowly, kiln-dries fairly rapidly but marked col-lapse may occur during the early stages of seasoning; collapse may be remedied by reconditioning; shrink-age-tangential (6.1%), volumetric (8.3 %) and radial (2.2 %)

Durability - Moderately durable, inner heart wood is subjected to heart rot. The wood is liable to be attacked by termites on ground contact

reatability: - Moderately resistant

Working Properties - A tough and hard timber easy to work with hand tools. Planing-easy; boring- easy; turning-easy; nailing-easy; finish- good.



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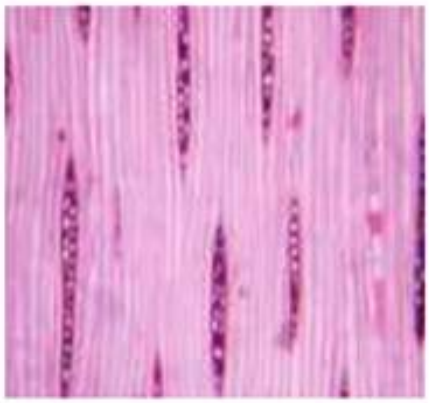


TLS (x100)

Gross features

Growth rings fairly distinct. Diffuse porous wood.

Vessels solitary and in radial multiples of two to three; large to medium-sized; moderately numerous (10-16 per mm2). Soft tissue forming a sheath around vessels.

Rays fine, numerous and closely spaced. Rays one to three-cell wide, homogeneous.Parenchyma paratracheal and vasicentric

14. MANGO

Trade Name	Mango wood
Vernacular Names	Maavu, moochi (Mal.), Aaam (Hin.)
Botanical Name	Mangifera indica Linn

Family Name	Anacardiaceae
Origin (Distribution	West coast tropical evergreen and West coast semi evergreen forests; cultivated extensively
Tree	Medium to large 15-30 m in height and 50-100 cm in diameter. Bark brown or dark grey, rough

Tree Flat Sawn Cross Cut

General features

Mangifera indica (mango wood) is a moderately hard and heavy wood. It has yellowish white to greyish brown and somewhat lustrous wood. To identify the wood, check the following

:• Growth rings are fairly distinct

• Wood is moderately hard and heavy

• Aliform to confluent parenchyma and often delimiting growth rings

• Rays are fine to moderately broad and numerous

• Vessels are large to medium, often filled with tyloses, numerous and soli-tary or in radial multiples of 2-3

Colour:- Yellowish white to greyish brown, sap wood and heart wood not dis-tinct or sometimes heartwood distinct and dark brown; somewhat lustrous.

Weight:- Moderately hard and moderately heavy. 690 kg/m3 at 12% m.c

Grain :- Straight to somewhat interlocked

Texture - Medium to coarse

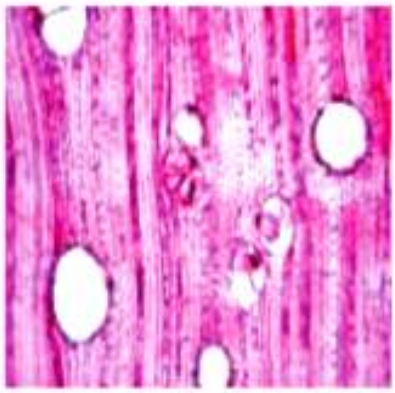
Strength - Strong

Drying and Shrinkage:- Not refractory; green conversion followed by stacking in dry ventilated area recommended. Kiln-seasoning improves the appearance of th timber without degra-dation. Retains its shape remarkably well seasoning. Shrinkage green to oven dry radial (3.2%); Tangential (4%)

Durability - Non-durable

Treatability: - Easily treatable

Working Properties: - Easy to saw, machining satisfactory, good polish. Nail and screw holding capacity excellent. Peels well.



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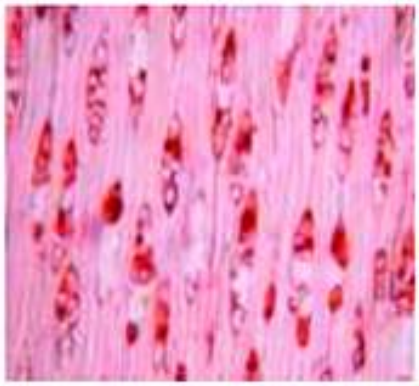


TLS (x100)

Gross features

Wood is diffuse porous.Growth rings fairly distinct.

Vessels large to medium, few to moderately numerous solitary or in radial multiples of 2-3 or more, often filled with tyloses.

Parenchyma paratracheal- aliform to confluent, often de-limiting growth rings.

Rays fine to moderately broad, numerous, closely spaced. Pith flecks are usually present.

15. MYSORE GUM

Trade Name	Mysore gum, Eucalyptus hybrid
Vernacular Names	Eucalyptus, Eucali (Mal.), Mysore gum, Forest red gum, Eucalypts (India), Queensland blue gum (Australia)

Botanical Name	Eucalyptus tereticornis Sm
Family Name	Myrtaceae
Origin (Distribution	Native of Australia extensively raised in plantations in many tropical and sub tropical countries including India for pulpwood production. Mostly seen in Uttar Pradesh, Mad-hya Pradesh, Karnataka, Tamil Nadu and West Bengal. It is also seen in Long Islands in Middle Andaman Division. It is indigenous to coastal districts of eastern Australia and Papua New Guinea. In India it is the most widely planted species upto 1,200 m elevation
Tree	Large, about 25-45 m in height, 3-6 m in girth, and straight bole of about 15-22 m and large open crown and 40 cm in diameter. Bark smooth, whitish or ash co-loured, deciduous decorticating in more or less long plates and irregularly blotched throughout, sometimes with a little rough and flaky bark persisting at base.

Tree Flat Sawn Cross Cut

General features

Eucalyptus tereticornis Sm. (Mysore gum) is a very hard and heavy wood. To identify the wood, check the following:

• Heartwood is pale brown to reddish brown

• Parenchyma: moderately abundant to abundant, apotracheal, diffuse

• Rays fine, closely and more or less evenly spaced

• Vessels medium sized, visible to the eye, moderately numerous (5-20 per mm2), mostly solitary, open or filled with abundant tyloses, kino-like depos-its sparse to moderately abundant.

Colour: - Heart wood pale brown to reddish brown fairly well demarcated form the sapwood. Sapwood light greyish-brown or pale red

Weight:- Lustrous, hard to very hard. Heavy to very heavy. Air dry specific gravity 980 kg/m3

Grain:- Straight to shallowly interlocked or wavy

Texture - Medium to coarse

Strength Moderately strong

Drying and Shrinkage: - Seasoning difficult, liable to warp and crack Shrinkage Green to oven- dry, Radial – 6.3%, Tangential – 9.6%. The high values for shrinkage indicate that the dimen-sional stability of the wood may be poor.

Durability - Moderately durable under cover

Treatability :- It is likely to be refractory to preservative treatment

Working Properties: - Planing easy, boring easy, turning easy; pre-boring necessary. Easy to saw and work, takes a good finish. Nail holding capacity is good

T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.Growth rings are indistinct.

Vessels medium, visible to the eye, moderately numer-ous(5-20 per mm2), mostly solitary, rarely in radial or oblique chains, round to oval, open or filled with abundant tyloses, kino-like deposits sparse to moderately abundant.

Parenchyma moderately abundant to abundant, apotra-cheal-diffuse to diffuse- in aggregates, kino-like deposits sparse to abundant. Parenchyma indistinct to distinct to the eye, distinct under hand lens forming thin sheet round the vessel

.**Rays** fine, closely and more or less evenly spaced, kino-like deposits abundant. Specific gravity of this species. varies in different localities.

16. NEEM

Trade Name	Neem
Vernacular Names	Aryaveppu, Veppu, Vempu, Leemdo, Kadunimb, Neem (India), Nim (Pakistan), Baypay (Malaysia) Kwinin (Thailand) , Mindi (Indonesia)
Botanical Name	Azadirachta indica A. Juss
Family Name	Meliaceae
Origin (Distribution	Native of Indian subcontinent; distributed throughout South- East Asia, East and Sub-Saharan Africa, Fiji and some parts of Central America. Naturally found in deciduous forests of Peninsular India and homesteads of Kerala
Tree	Medium to large tree with a height of 15-20 m with a clear bole of 7 m and diameter of 50 cm.

Tree Flat Sawn Cross Cut

General features

Azadirachta indica A. Juss (Neem) is a moderately heavy wood.To identify the wood, check the following:

• Heartwood is reddish brown, aromatic and slightly lustrous

• Distinct growth rings

• Parenchyma: Apotracheal, paratracheal- vasicentric, also in tangential lines connecting vessels

• Vessels medium sized, few and occurring in solitary or in radial multiples of two to three, often in clusters and filled with reddish gummy deposits

Colour:- Heartwood reddish brown, aromatic, moderately lustrous. Sapwood is yellowish white, yellowish brown or greyish yellow.

Weight:- Hard to moderately hard; moderately heavy. (835 kg/m3 at 12% m.c)

Grain: - Interlocked

Texture - Coarse

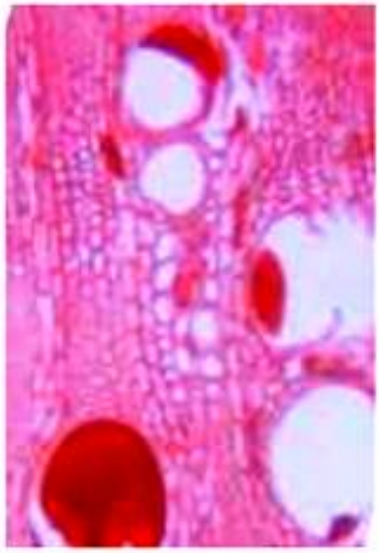
Strength – Strong

Drying and Shrinkage:- Dries well. Green conversion followed by open stack-ing under cover recommended; Shrinkage- green to oven dry; Radial (4.5%), Tangential (6.2%) volumetric (10.7%)

Durability - Durable, resistant to termite damage.

Treatability :- Resistant

Working Properties: - Planing-easy, boring-easy, Turning-easy, Nailing-good, but pre-boring necessary; Finish-good. Sawing and machining fairly good, gives fair finish.



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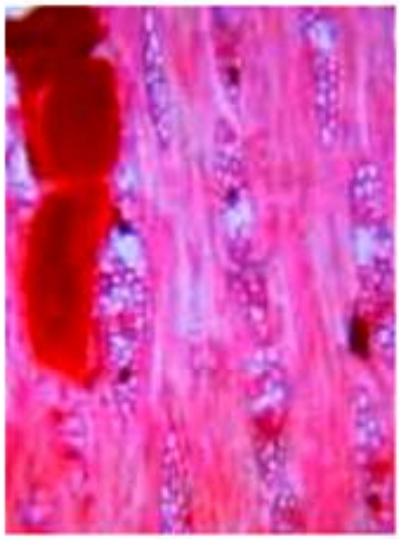


TLS (x100)

Gross features

Growth rings distinct.

Vessels medium, few to moderately few, solitary or in radial multiples of two to three, often in clusters; numerous (16-20 per mm2). Vessels filled with reddish gummy depos-its. Soft tissue forms bands delimiting growth ring and also associated with vessels.

Parenchyma – Apotracheal-irregularly placed tangential and continuous bands delimiting growth rings, Paratrache-al- Vasicentric, also in tangential lines connecting vessels.

Rays fine to medium sized, numerous and somewhat widely spaced.

Special Features

The wood possesses characteristic odour. The wood has insect repellant properties due to the presence of neem oil. Gum canals often present in tangential bands.

17. NEERMARUTHU

Trade Name	Arjun
Vernacular Names	Arjun (Beng., Hind., or.), Arjuna- sadada (Guj.), Holematti, Nadiam (Kan.),Kahu, Sandura (Mar.), Kula muruthu, Vella marda (Ta m.),Yermaddi (Tel.)
Botanical Name	Terminalia arjuna Bedd.
Family Name	Combretaceae
Origin (Distribution	The tree occurs throughout greater part of the Peninsula from Avadh Southwards on banks of streams. It is found in Bihar, orissa, coastal Andhra Pradesh, the Deccan and Central India, but uncommon in Tamil Nadu Except in Tirunelveli. It occurs on the West Coast from Gujarat southwards. It also occurs locally along banks of streams in sub-Himalayan tract in Uttar Pradesh and Himachal Pradesh.The tree is extensively planted for shade and ornament in avenues and parks.
Tree	Large evergreen tree with spreading crown and drooping branchlets, 18-24 high and over 3 m in girth. The bole is rarely long or straight and is usually buttressed and often fluted.Bark is pale greenish-grey and smooth.

Tree Flat Sawn Cross Cut

General features

Terminalia arjuna (Neermaruthu) is a hard and heavy wood. To identify the wood, check the following:

• Sapwood is reddish-white and the heartwood, which is sharply delineated from the sapwood, is brown to dark brown variegated with darker coloured streaks.

• Wood is diffuse-porous.

• Growth rings delimited by fine concentric lines of soft tissues which are distinct only under hand lens.

• Vessels - The pores are large, distinct to the eye, few, more or less evenly distributed solitary or in radial multiples of 2-3, partially filled with tyloses and also reddish-brown gummy deposits in the heartwood.

• Soft tissues form sheath or eye lets round the pores which are usually distinct to the eye, occasionally also with short lateral extensions which connect adjoining pores

.• Rays are fine to very fine, distinct only under hand lens.

Colour:- Sapwood is reddish-white and the heartwood, which is sharply de-lineated from the

sapwood, is brown to dark brown variegated with darker coloured streaks.

Weight:- Hard and heavy. Air-dry weight about 800 kg/cum

Grain:- Interlocked

Texture - Coarse

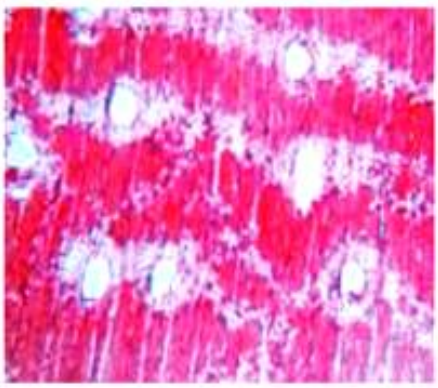
Strength – Strong

Drying and Shrinkage:- Difficult to air-dry as it is liable to warping and split-ting. Radial shrinkage 4%, tangential 7%, volumetric12%.

Durability - Durable

Treatability: - Heartwood response to treatment is reported to be good, but completepenetration may not be always achieved.

Working Properties: - Difficult to work, but with care can be brought to a fine finish, and takes lasting polish



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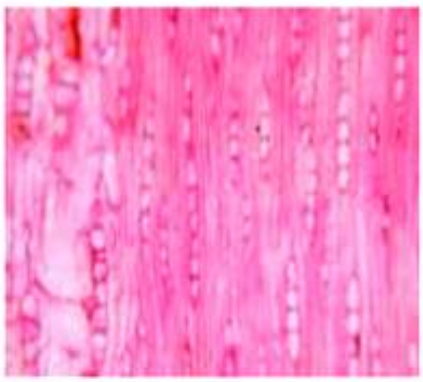

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Gross features

Wood is diffuse-porous.

Growth rings delimited by fine concentric lines of soft tissues which are distinct only under hand lens.

Vessels - The pores are large, distinct to the eye, few, more or less evenly distributed solitary or in radial multiples of 2-3, partially filled with tyloses and also reddish-brown gummy deposits in the heartwood. Soft tissues form sheath or eye lets round the pores which are usually distinct to the eye, occasionally also with short lateral extensions which connect adjoining pores.

Rays are fine to very fine, distinct only under hand lens.

18. RED SANDERS

Trade Name	Red sanders
Vernacular Names	Yerra chandanam, yerra sandanam (Tel.); chemmaram, sevapu chamdrium (Ta m.); Raktha chandanam (Mal.), Lal chandan, (Hind.); Kempu gandha, rakta chandana (Kan.)
Botanical Name	Pterocarpus santalinus L. f

Family Name	Leguminosae (Fabaceae)
Origin (Distribution	Southern moist mixed deciduous forest, moist teak bearing forest, west coast semi-evergreen and southern dry mixed deciduous forests. It occurs gregariously on the dry hill slopes of the Eastern Ghats. Endemic to Andhra Pradesh and Tamil Nadu.
Tree	A moderate sized tree, upto 10 m in height with a clear bole of 4.5-6 m and35 cm in diameter; 1 m in girth but may attain 1.5 m in girth. Bark dark dirty- brown, rough with deep vertical and horizontal cracks

General features

Pterocarpus santalinus L. f (Red sanders) is a heavy wood. To identify the wood, check the following:

• Heartwood dark orange red with darker streaks when freshly cut, turning deep red to purplish black on exposure

• Wood is hard to very hard, very heavy

• Parenchyma paratracheal, aliform and narrow aliform confluent but also forms narrow confluent wavy bands, also marginal and as diffuse scattered cells, strands storied.

• Rays fine to very fine, somewhat closely spaced, and uniformly distributed.

• Vessels moderately large to small, just visible to eye, few to moderately few (3-12 per mm2), solitary or in radial multiples of two to three, frequently filled with reddish brown gummy deposits.

Colour:- Heartwood and sapwood clearly demarcated. Sapwood yellowish white, heartwood dark orange red with darker streaks when freshly cut, turning deep red to purplish black on exposure.

Weight:- Wood is hard to very hard, very heavy (1120 kg/m3 at 12 % m. c

Grain: - Interlocked to wavy grain

Texture - Medium-fine

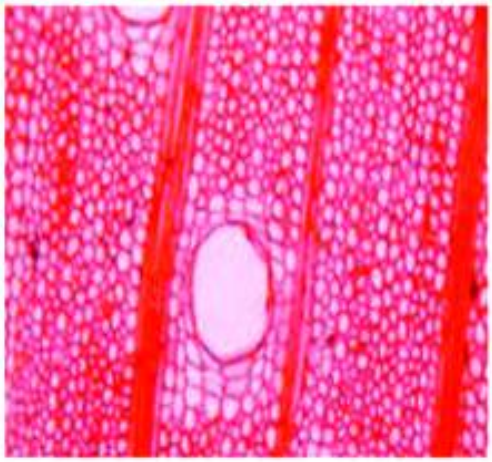
Strength - Extremely strong

Drying and Shrinkage: - Seasons well; Radial 2 %; Tangential 6%; Volumetric 8 %

Durability - Very durable

Treatability: - It does not need preservative treatment

Working Properties: - It is difficult to saw and work, but can be turned and carved exceptionally well. It works fairly well with hand-tools.



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Gross features

Growth rings are indistinct or barely visible even under the hand lens. Diffuse porous wood.

Vessels moderately large to small, just visible to eye, few to moderately few (3-12 per mm2), solitary or in radial multiples of two to three, frequently filled with reddish brown gummy deposits. Soft tissue narrow, broken to fairly continuous bands often connecting the vessels, sometimes appearing as aliform with fine short or long lateral extensions and also a fine interrupted line delimiting growth rings.

Rays fine to very fine, somewhat closely spaced, and uni-formly distributed. Ripple marks are present, distinct in the sap wood under hand lens but usually inconspicuous in heartwood.

Parenchyma aliform and narrow aliform confluent but also forms narrow confluent wavy bands, also marginal and dif-fuse scattered cells, strands storied and fusiform.

19. ROSE WOOD

Trade Name	Rosewood
Vernacular Names	Sitsal (Beng), Seris (Gon.), Sissu (Guj.), Pahari, sissu, saise, sirsai, sissui,sitsal (Hind.), bide, bidi, biti, (Kan.), kiri, rute (Kol.), Colavitti, Etti, Ilti, Karitti, Veetti, Vitti, Blackwood (Mal.), Shisham, Bhotbeula (Mar.), Satisal (Nep.), Sissua (or.), mahle, satsaye (Sant.), eruvade, itti, karundorviral (Ta m.), cottage, jilegi, virugudu chava (Te l.), setisar (Th.)
Botanical Name	Dalbergia latifolia Roxb.

Family Name	Leguminosae
Origin (Distribution	West coast semi-evergreen, moist teak bearing and southern secondary moist mixed deciduous forests. It is distributed in the Peninsula, Andaman Islands, Bihar, Gujarat, Rajasthan, Sikkim, Uttar Pradesh, West Bengal, Nepal and Malaysia.
Tree	Medium to large sized tree reaching a height of 15-30 m and upto 130 cm in diameter. Bark about 12 mm thick, grey to rusty brown with irregular short cracks peeling off in small flakes.

General features

Dalbergia latifolia Roxb. (Rosewood) is a hardwood. To identify the wood, check the following:

• Heartwood is purplish brown with black or red streaks

• Wood is hard and heavy

• Parenchyma: paratracheal- aliform to confluent and banded, also fine or interrupted lines

• Rays are fine to very fine, closely spaced and numerous

• Vessels solitary and often in radial multiples of two to four, large, small to medium sized occasionally filled with gummy deposits

• Soft tissue forming diamond- shaped patches around vessels which are sometimes interconnected to form bands.

Colour: - Heartwood purplish brown with black or red streaks producing an attractive figure, color uniform. Sapwood is pale yellowish white with pinkish tinge

Weight:- Hard, heavy (815 kg/m3 at 12% m.c.)

Grain:- Straight to shallowly interlocked.

Texture - Medium

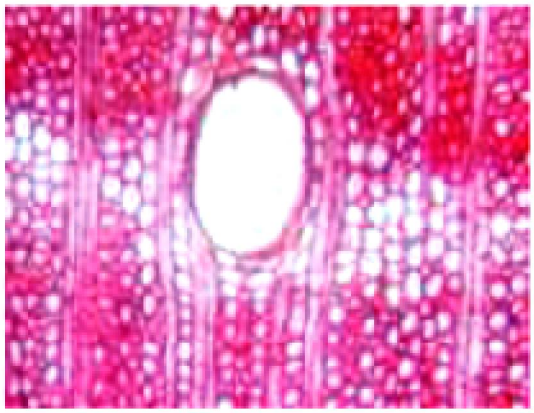
Strength – Strong

Drying and Shrinkage:- offers no difficulty in seasoning, if carefully stacked undercover. Can be kiln- seasoned without difficulty. Shrinkage- green to oven dry radial(2.3%), tangential(5.6%).

Durability - Very durable

Treatability: - Sapwood perishable but readily treatable with com-plete penetration.

Working Properties: - Works comparatively easy with hand and machine, can be brought to a fine finish and takes good polish. Peels and slices well and very thin veneers can be obtained.



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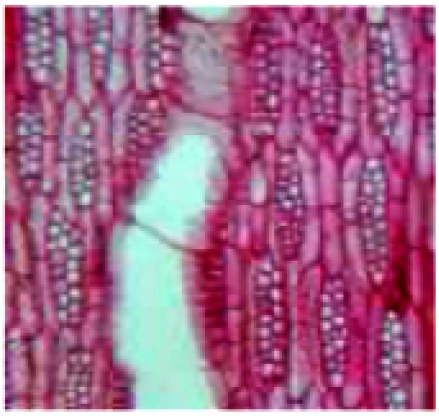


TLS (x100)

Gross features

Wood is diffuse porous, rarely with a tendency to semi- ring- porous.Growth rings scarcely distinct.Vessels solitary and often in radial multiples of two to four, large, small to medium-sized, not clearly visible to the naked eye, few to moderately numerous (8-12 per mm2).

Vessels occasionally filled with gummy deposits.Soft tissue forming diamond- shaped patches around vessels which are sometimes interconnected to form bands; discon-tinuous bands delimiting growth rings also present.

Rays fine to very fine, closely spaced and numerous. Paren-chyma paratracheal-aliform to confluent and banded, also fine or interrupted lines.

20. RUBBER

Trade Name	Rubber
Vernacular Names	Rubber tree
Botanical Name	Hevea braziliensis (HBK)Muell. Arg
Family Name	Euphorbiaceae
Origin (Distribution	Native of Brazil; raised extensively in plantations in Malaysia, Indonesia, Thailand, SriLanka and India for latex production.
Tree	Large tree reaching a height of 30m and diameter of 40-70 cm, bark greyish-black, smooth.

General features

Hevea braziliensis (HBK) Muell. Arg. (Rubber) is a soft and light timber. To identify the wood, check the following:

• Wood is white to creamy in colour

• Wood is light to moderately heavy

• Parenchyma: abundant, apotracheal-diffuse, tangential wavy lines and also in more or less continuous fine line delimiting growth rings, paratracheal- vasicentric.

• Rays fine, somewhat closely spaced.

• Vessels medium to small moderately numerous to few, solitary or in radial multiples of 3 or 4, occasionally with tyloses and white to chalky deposits.

Colour: - Heartwood and sapwood are not distinct. Wood is white to creamy in colour when freshly cut, some-times with a pinkish ting, turns to light brown or creamy white on exposure.

Weight: - Light to moderately heavy; (525-610 kg/m³ at 12% m. c).

Grain: - Straight

Texture - Even and medium textured

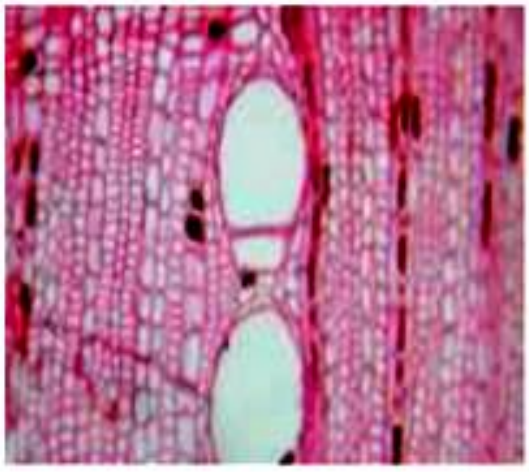
Strength - Moderately strong

Drying and Shrinkage:- Dries easily; but care is needed to avoid seasoning defects such as cupping, twisting, bowing, checking and splitting; a conventional kiln seasoning (steam-heated, forced-air drying system) is preferred in drying, shrinkage-radial (1.2%), tangential (1.8%), volumetric (3.0%)

Durability - Perishable, the wood has to be treated with preservatives soon after felling (preferably with for 48 hrs.) liable to discolouration caused by sap stain fungi and attack by pinhole and powder post beetles

Treatability :- Easy. Simple dip treatment or vacuum- pressure impregnation process with preservatives such as borax-boric acid and copper-chrome arsenate (CCA) with adequate retention will protect the wood from fungal and insect attack.

Working Properties: - Planing-easy; boring-easy; Turning-easy; Nailing-good, but pre-boring necessary; Finish-good. Tension wood can lead to fuzzy grain when machined. Finger jointing is often applied to achieve larger dimensions. Rubber wood can be stream bent with good results. It can easily be stained to resemble teak, rosewood, walnut, cherry, oak or other woods, depending on consumer demand.



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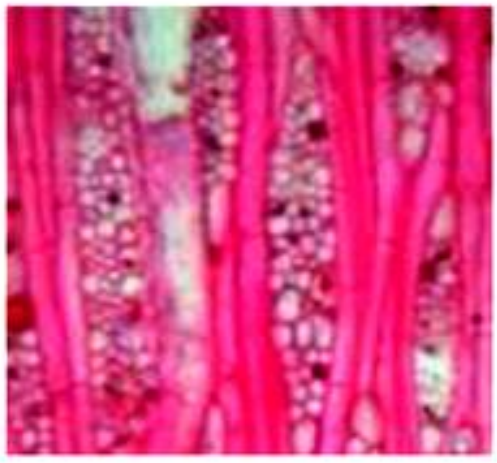


TLS (x100)

Gross feature

Growth rings indistinct, but sometimes appearing as faint impressions due to comparatively thick walled fibrous tissues.Diffuse porous wood.

Vessels medium to small moderately numerous to few, solitary or in radial multiples of 3 or 4, occasionally with tyloses and white to chalky deposits, oval in outline.

Parenchyma abundant, apotracheal- diffuse, tangential wavy lines, touch-ing the vessels and also in more or less continuous fine line delimiting growth rings, paratracheal- vasicentric.

Rays fine, light in colour uniformly distributed and somewhat closely spaced.

21. SEMUL

Trade Name	Semul
Vernacular Names	Himila (Asm.), Simal(Beng.), Khatsaweri (Bhil.), Shimal (Garhwal), Bolchu (Garo.), Bargu (Gon.), Sawar (Guj.), Semul, Semur (Hind.), Bonju-phang (Kach), Shimlo (Kamrup), Burla (Kan.), Savar (Mar.), Simbal (Punj.), Illavam (Ta m.), Buraga (Te l.), Mullilavu, Poola, Cotton tree (Mal.)
Botanical Name	Bombax ceiba L.Syn . Bombax malabaricum (DC.) Salmalia malabarica (DC.) Schott. and Endl.
Family Name	Bombacaceae
Origin (Distribution	Widely distributed throughout India, except in very arid tracts, ascending to over 1,500 m. Commonly it is seen in west coast semi evergreen, southern moist mixed deciduous and moist teak bearing forests. occasionally it tends to be gregarious on alluvial soils near river banks, also occur in Myanmar.
Tree	Large to very large, deciduous 25-40 m in height with a clear bole of 15-25 m and upto 150cm in diameter, 3 m in girth; huge buttressed 4.5-6 m in height. Under favourable con-dition it grows to enormous sized trees 59 m in height and 4.5 m in girth. on poor soil and higher elevations, it is usually stunted. Bark grey, covered with conical prickles when young, deeply cracked when old, outer bark fleshy and soft, inner fibrous, upto 2.5 cm in thickness.

General features

Bombax ceiba is a light wood. To identify the wood, check the following:

• Heart wood and sap wood are not distinct. Creamy white to pale yellowish-brown or yellowish-brown, grey-ish brown on exposure, often lustrous showing silver effect on radial surface.

• Diffuse porous wood• Growth rings not always distinct to the eye, but clearly visible under hand lens, delimited by the slightly denser latewood and closely spaced bands of parenchyma,

• Parenchyma predominantly apotracheal-visible only under the lens, diffuse to diffuse-in-aggregate, closely spaced, fine interrupted tangential line forming reticulum with rays

• Vessels very large to large, clearly visible to the eye, very few to few, scanty, mostly solitary or in radial mul-tiples of 2 or 3,oval in outline, usually open or partly filled with tyloses.

• Rays fine to very broad, widely spaced, forming conspicuous flecks on radial surface, distinct only under lens, interspersed with broader rays sometimes tending to be storied. Ripple marks usually present.

Colour: - Heart wood and sap wood are not distinct. Creamy white to pale yellowish-brown or yellowish-brown, greyish brown on exposure, often lustrous showing silver effect on radial surface.

Weight: - Very light to light (365kg/m3 at 12% m.c)

Grain: - Straight

Texture - Coarse

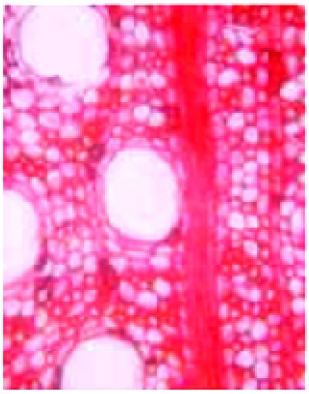
Strength - Weak

Drying and Shrinkage: - Very easy to season; quick conversion and open stacking under cover recommend. Shrinkage-Green to oven dry, radial-2.3, Tangential-5.1, Volumetric-7.4

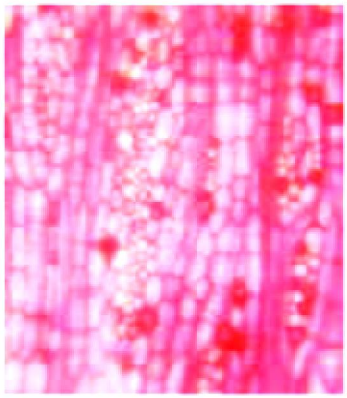
Durability – Perishable

Treatability: - Heartwood easily treatable with preservatives, penetration being complete.

Working Properties: - Easy to saw; peels and glues well, however, absorbs too much paint and varnish.



T S (x100)



TLS (x100)

Gross features

Wood is diffuse porous .Growth rings not always distinct to the eye, but clearly visible under hand lens, delim-ited by the slightly denser latewood and closely spaced bands of parenchyma, usually less than 2 per cm.

Vessels very large to large, clearly visible to the eye, very few to few, usually more or less evenly distributed, scanty, mostly solitary or in radial multiples of 2 or 3,oval in out-line, usually open or partly filled with tyloses, vessel lines conspicuous on the longitudi-nal surfaces, vessel elements being individually distinct 20-25 per cm.

Parenchyma predominantly apotracheal-visible only under the lens diffuse to diffuse-in-aggregate, closely spaced, fine interrupted tangential line forming reticulum with rays. Lines of parenchyma same or wider than fibre layers, 10-15 per mm. **Rays** fine to very broad,

widely spaced, forming conspicuous flecks on radial surface, just visible or indistinct to the eye, distinct only under lens, interspersed with broader rays sometimes tending to be storied. Ripple marks usually present, distinct to just visible to the eye, but sometimes under the lens, 20-22 per cm due to storied parenchyma

22. SHAITAN WOOD

Trade Name	Shaithan wood
Vernacular Names	Satian (Hind.), Dodapale (Kan), Ezhilam pala, manglapala (Mal.), Chatiwan (Nep.), pale garuda, Elalaipalai (Ta m.), Yedakalapala (Te l.)
Botanical Name	Alstonia scholaris R.Br
Family Name	Apocynaceae
Origin (Distribution	It occurs throughout the moist regions of India especially on the West coast, Pakistan, Sri Lanka, Burma, Thailand, Laos, Vietnam, Cambodia, and Malaysia. Found naturally occurring in Southern moist mixed deciduous and moist teak bearing forests.
Tree	Evergreen, medium to large up to 30 m in height with a clear bole of 6-15 m and about 60-180 cm in diameter. Buttressed at the base. Bark grayish brown, rough, lenticellate, 13 mm thick, inner bark yellow with much milky juice.

Tree Flat Sawn Cross Cut

General features

Alstonia scholaris (shaitan wood) is a light weight wood. To identify the wood, check the following:

• White to yellowish white wood often discolored due to sap stain and is lustrous.

• Wood is light to very light and soft

• Parenchyma is visible to the eye and is fine, paratracheal (vasicentric) and as wavy, concentric lines connecting the vessels.

• Rays are very fine

• Vessels are small, solitary and in radial multiples of 2 to 3 or 5

Colour:Heartwood - not distinct, basically white to yellowish white or pale brown or grey; often discoloured due to sap stain, lustrous. Sap-wood colour similar to heartwood colour.

Weight - Light to very light. Basic specific gravity 350-465kg/m³ at 12% m.c

.Grain - Straight

Texture - Medium to fine textured

Strength - Soft and light

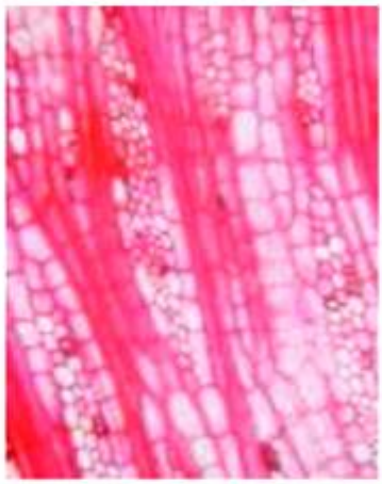
Drying and Shrinkage - Green conversion and soaking in water before seasoning recommended.

Durability - Non durable

Treatability - Extremely resistant

Working Properties: - Easy to saw; peels and glues well, however, absorbs too much paint and varnish

T S (x100)



TLS (x100)

Gross features

Wood is diffuse-porous.Growth ring boundaries indistinct.

Vessels small to medium, few, occasionally solitary mostly in radial multiples of two, three or often five (5-12/ mm2); distinct under the hand lens, few to moderately numerous (5-12 per mm2), occasionally filled with tyloses and yellow-ish gummy deposits, usually open, vessel line distinct

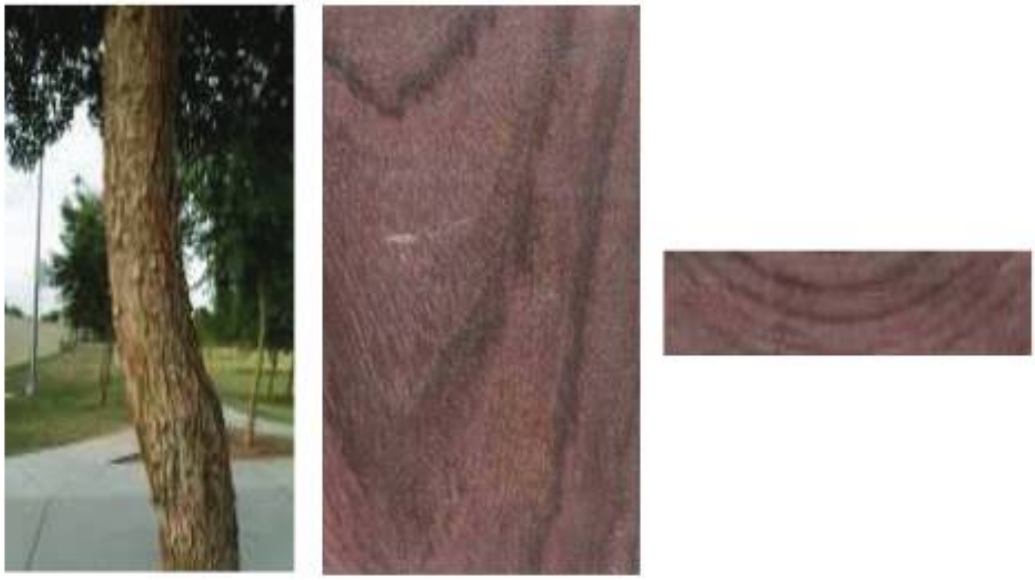
.**Parenchyma** visible to the eye, fine, paratracheal- vasicen-tric and in wavy, concentric lines connecting the vessels; apotracheal-diffuse; crystals often present.‘

Rays fine to very fine, distinct under hand lens, closely and evenly spaced; crystals occasionally present, yellow gummy infiltration sparse. Wood is soft.

23. SHISHAM

Trade Name	Sissoo
Vernacular Names	Shisham, Sissoo (India), Sissou (Nepal), Hihu (Asm.), Sisam, Shishma (Guj.), Agara, Birdi (Kan.), Shishai (Punj.), Shinshapa (San.), Gette, Yette (Ta m.), Sinsupa (Te l.)
Botanical Name	Dalbergia sissoo Roxb
Family Name	Leguminosae (Fabaceae)
Origin (Distribution	Punjab to Assam in the Sub-Himalayan tract in India and Nepal, Bangladesh, Bhutan, Myanmar, Afghanistan, Pakistan, Iran and Iraq.

Tree	Small to large up to 30 m in height with curved or crooked and buttressed stem. Bark grey or brown, longitudinally and somewhat reticulately furrowed, thick



General features

Heartwood of Dalbergia sissoo (Shisham) is golden brown to dark brown with deep dark streaks. To identify the wood, check the following:

• Hard and moderately heavy wood

• Growth rings are distinct to indistinct, demarcated by a fine line of parenchyma

• Parenchyma is aliform to aliform confluent, also forming straight to wavy narrow bands in late Wood

• Vessels are large and few in early wood and small and few in late wood, often filled with dark, gummy deposits, solitary and in radial multiples of 2 or 3

Colour:- Heartwood golden brown to dark brown with deep dark streaks, soon becoming dull, clearly demarcated from the pale brownish to white sapwood.

Weight:- Hard and moderately heavy; 820 kg/m3 at 12 % m. C

Grain:- Narrowly interlocked

Texture - Medium to coarse

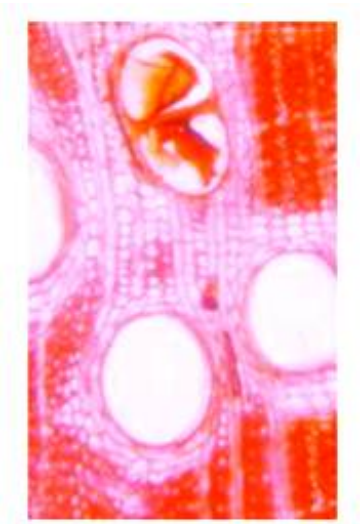
Strength – Strong

Drying and Shrinkage:- Seasons slowly with little degrade; kiln- seasoning enhances the value of the timber by darkening the colour. Shrinkage- radial (3%), Tangential (5.4%), Volumetric (8.4%)

Durability - Very durable, highly resistant to termites

Treatability - Extremely resistant

Working Properties -Planing-easy; Boring-easy; Turning-easy; Nailing-good, but pre-boring necessary; Finish-good.



T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.Growth rings are distinct to indistinct, demarcated by a fine line of parenchyma but indistinct or inconspicuous.

Vessels large to small, few to moderately few, rather unevenly distributed, gener-ally larger and comparatively more numerous in early wood, mostly solitary and in radial multiples, open but occasionally filled with white or dark, gummy deposits, perforation simple, inter vessel pits vestured and small to medium sized.

Parenchyma aliform to aliform confluent also forming straight to wavy narrow bands in late wood. Terminal or marginal, delimiting growth rings, strands are storied, fusiform often subdivided into crystalliferous locules.Fibres libriform, round to angular in cross section, often gelatinous, non-septate, storied, inter fibre pits small, simple to narrow bordered.

Rays mostly uniseriate but may be up to 2 or 3 ceriate, 7-16/mm, homogenous weakly heterogenous composed of mainly of procumbent cells..

24. SILVER OAK

Trade Name	Silver oak
Vernacular Names	Southern silky-oak (Australia), Lacewood (USA), Silky-oak (Indonesia), Savukkuma-ram (Ta m.)
Botanical Name	Grevillea robusta A. Cunn. Ex R. Br.
Family Name	Proteaceae
Origin (Distribution	Native to Eastern Malaysia, New Caledonia and Australia, extensively planted as a shade tree for coffee and tea plantations in Africa, India, Sri Lanka and other parts of the world
Tree	An evergreen tree attaining a fair height with long conical crown. Medium to large18-25 m in height and about 65 cm in diameter. Bark dark grey and rough with vertical fissures.

Tree Flat Sawn Cross Cut

General features

Grevillea robusta A. Cunn. Ex R. Br. (Silver oak) is a hard and moderately heavy timber. To identify the wood, check the following

• Wood is pinkish brown becoming yellow brown on exposure

• Parenchyma paratracheal- vasicentric and aliform to aliform- confluent, just visible to the naked eye

• Rays are of two types; broad to very broad and fine to very fine.

• Vessels large to medium, moderately numerous (3-9/ mm2), mostly in tan-gential rows filled with deposits and separated by fibrous tissue in alternate fashion, usually in irregular

clusters or short radial or tangential multiples, rarely solitary, round to oval, mostly open and vessel lines distinct.

Colour:- Heartwood distinctly pinkish brown becoming yellow brown on exposure, lustrous, well demarcated from the cream coloured sap-wood.

Weight:- Hard and moderately heavy

Grain:- Straight to wavy

Texture - Medium to coarse

Strength- Strong

Drying and Shrinkage:- Dries slowly, shrinkage-radial (3.2%), tangential (9.6%), volumetric (12.8%)

Durability - Moderately durable or perishable

Treatability: - Treatable by the diffusion process and complete penetration of the pre servative both in the sapwood and heartwood is obtained. It is moderately resistant.

Working Properties: -Planing-easy, Boring-easy, Turning-easy, Nailing-easy, Finish-good.

T S (x100)

TLS (x100)

Gross features

Wood is diffuse porous.Growth rings are fairly distinct.

Vessels large to medium, moderately numerous (3-9/mm2), mostly in tangential rows filled with deposits and separated by fibrous tissue in alternate fashion, usually in irregular clusters or short radial or tangential multiples, rarely solitary, round to oval, mostly open and vessel lines distinct.

Parenchyma paratracheal- vasicentric and aliform to aliform-confluent, just vis-ible to the naked eye, distinct under hand lens in closely spaced lines enclosing or connecting the vessels tangentially (18-34/ cm)

Rays are of two types; broad to very broad and fine to very fine, the former prominent to the naked eye, widely spaced and the later rarely visible under the hand lens. Prominent silvery radial flecks present. Gum canals of traumatic type occasionally present in tangential rows.

25. TEAK

Trade Name	Teak
Vernacular Names	Jati, Tek (Indonesia), Java teak (Germany), Kyun (Myanmar), Teca (Brazil), Segan (Beng.), saga, sagach (Guj.), sagon, Sagwan (Hind.), Tega (Kan.), Sag, Saga (Mar.), Singua (or.), Tekku, Tekkumaram (Ta m.), Adaviteeku , Peedateeku (Te l.)
Botanical Name	Tectona grandis Linn.f.
Family Name	Verbenaceae
Origin (Distribution	It is a deciduous tree with a rounded crown which under favourable conditions attains large size with a clean cylindrical bole often becoming buttressed and fluted
Tree	The tree is large to very large, 25-45 m in height and upto 190 cm in diameter, but in the dry hot areas of Madhya Pradesh, Gujarat and Rajasthan the tree is comparatively smaller, often branchy and much fluted in advanced age. Bark light brown or grey with shallow longitudinal furrows and fibrous, about 0.4-1.8 cm thick, exfoliating in long thick strips.

Tree

Flat Sawn

Cross Cut

General features

Tectona grandis (teak) has golden brown heart wood with black streaks. However, wide variation in colour is present between teak available from different regions. The heartwood has an oily feel with a distinct smell resem-bling old leather. Teak is a typical ring porous hard wood. The early wood vessels are large and few, compared to the late wood vessels which are small and numerous. To identify the wood, check the following

• Wood is moderately hard and moderately heavy

• Parenchyma is paratracheal (vasicentric and in broad bands); distinct to the eye in the early wood, forming a continuous zone enclosing the vessel along with initial band of parenchyma delimiting growth

• Vessels are filed

Colour:- Sapwood and heartwood sharply demarcated. Heartwood golden brown when fresh or dark brown on exposure occasionally with black streaks with a waxy feel, lustrous sometimes with white glisten-ing deposit, distinct aromatic odour with the smell of leather. Sapwood white, pale yellow or grey. Well defined.

Weight:- Moderately hard and moderately heavy (650 kg/m3 at 12 % m. c)

Grain: - Straight, sometimes wavy.

Texture - Coarse

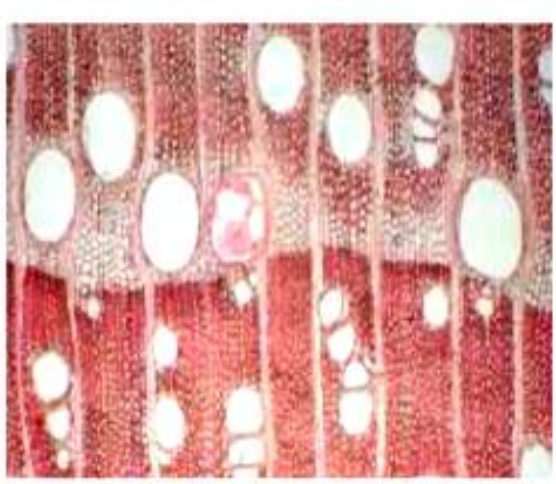
Strength – Strong

Drying and Shrinkage: - Dries well but rather slowly with little or no degradation. Seasons very well, the best model wood for air seasoning; kiln seasoning also good for very good results. Shrinkage radial (2.3%), tangential (4.8%), volumetric (7.1%). High resis-tance to water absorption

Durability - Very durable, highly resistant to termite damage.

Treatability - Extremely resistant; heart wood very refractory to treatment.

Working Properties: - Easily worked with both hand and machine tools. Planing easy, boring easy, turning- rather easy, nailing-good but pre-boring necessary, finish good.



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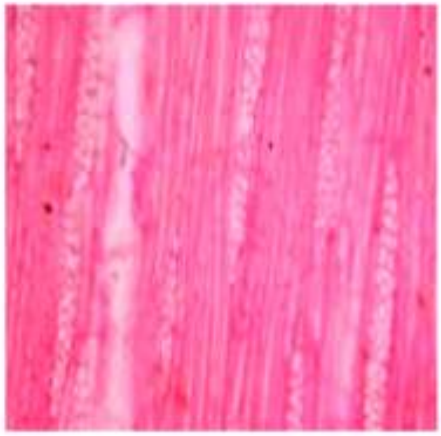


TLS (x100)

Gross features

Wood is ring porous.Growth rings are distinct, delimited with early wood vessels enclosed in parenchyma-tous tissues, less than 1-6/ cm. Vessels large in early wood, oval in out line, occasion-ally filled with tyloses and yellowish-white powdery deposits.

Vessels medium to small in late wood, mostly solitary or in short radial multiples, round to oval in out line, vessel lines of the early wood zone conspicuous on longitudinal surfaces.

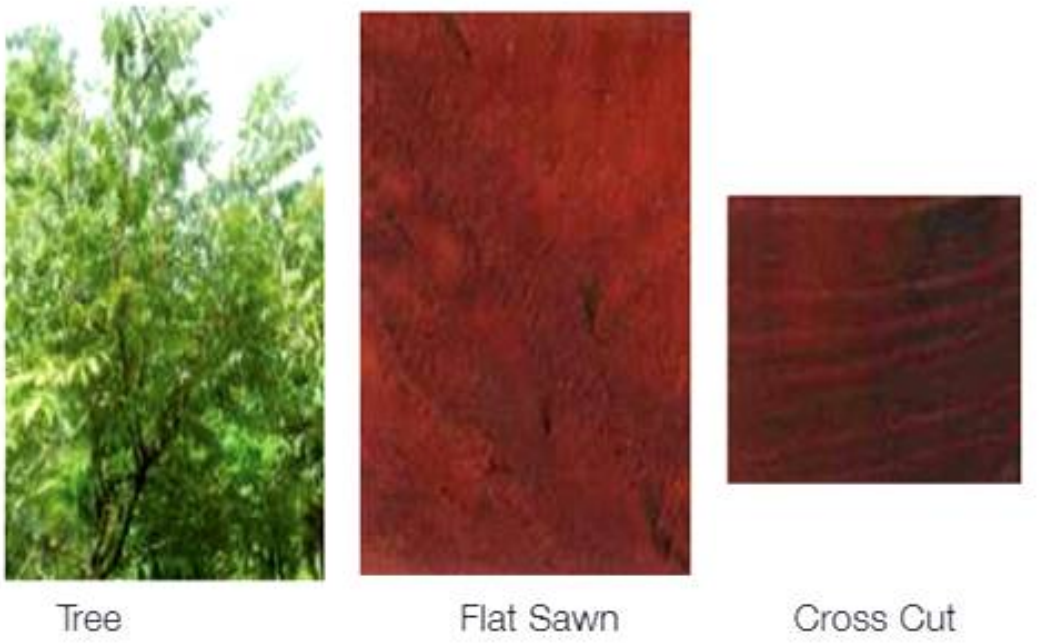
Parenchyma paratracheal- vasicentric and in broad bands, distinct under the hand lens but distinct to the eye in the early wood forming a continuous zone enclosing the vessel along with initial band of parenchyma delimiting growth rings.

Rays moderately broad, fairly wide spaced and uniformly distributed; visible to the eye, distinct under the lens.

26. TOON

Trade Name	Toon
Vernacular Names	Calantas , Danupra (Philippines), Chomcha (Cambodia), Ranggog (Sabah), Madagiri-Vempu, Toon , Vempu, Chandana Vempu, Chuvannaagil (India)
Botanical Name	Toona ciliata RoemerSyn. Cedrela toona Roxb.ex.Rottler
Family Name	Meliaceae
Origin (Distribution	Indigenous to Thailand, Myanmar, Pakistan and India. West-coast tropical evergreen, southern hill-top tropical evergreen, west coast semi-ever green and occasionally moist teak bearing forests.

Tree	Large, 20-30 m in height with a clear bole of 9-12 m and 60-90 cm in diameter. Bark greyish-brown, thick, rough, exfoliating in irregular woody scales in old trees.



General features

Toona ciliata (Toon) is a light wood. To identify the wood, check the following:

• Heartwood reddish- brown with a spicy odour, rather lustrous;

• sapwood pinkish-brown or greyish white.

• Wood is semi ring-porous to ring- porous. Growth rings are distinct

• Vessels are large in the early wood, transition from early wood to late wood gradual, small and moderately few in late wood, solitary or in radial mul-tiples of two or three; occasionally filled with dark brown gummy deposits.

• Parenchyma paratracheal-scanty, faintly delimiting growth rings.

• Rays moderately broad to fine, rather few, fairly wide spaced.

• Gum canals vertical, traumatic, occasional. Pith flecks often present

Colour: - Heartwood reddish- brown with a spicy odour, rather lustrous; sap-wood pinkish-brown or greyish white.

Weight:- -Light to moderately heavy (515 kg/ m3 at 12 % m.c)

Grain: - Straight

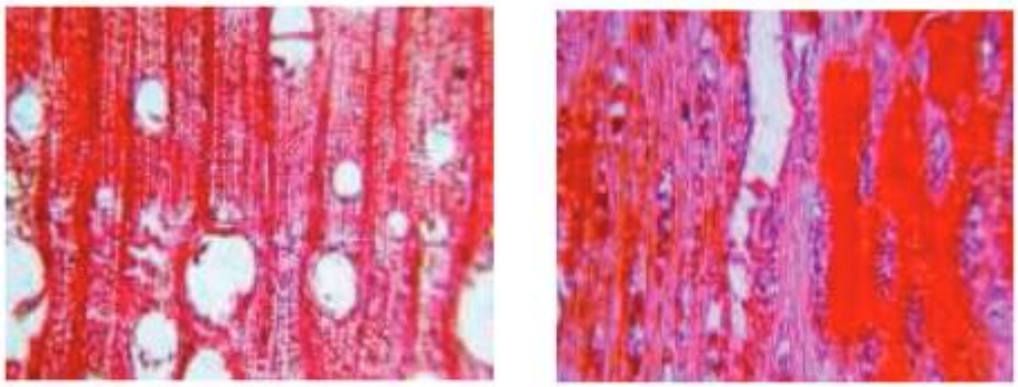
Texture - Coarse to medium

Strength - Moderately strong

Drying and Shrinkage:- Dries easily; shrinkage-radial (3.8%), Tangential (6.3%), Volumetric(10.1%). Refractory to seasoning, liable to warp, green conversion and careful stacking under cover recommended.

Durability - PerishableTreatability: Easy; heart wood only partially treatable.

Working Properties: - Planing-easy; Boring- easy to difficult; Turning-easy; Nailing-good; Finish- good.



T S (x100) TLS (x100)

Gross features

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.Vessels are large in the early wood, transition from early wood to late wood gradual, small and moderately few in late wood, solitary or in radial multiples of two or three; oc-casionally filled with dark brown gummy deposits.

Parenchyma paratracheal-scanty, faintly delimiting growth rings.

Rays moderately broad to fine, rather few, fairly wide spaced. Gum canals vertical, traumatic, occasional. Pith flecks often present

2.5 Poperties wood, defects and abnormalities

2.5.1 physical properties of wood

The physical nature of wood. Basically all the physical properties of wood are determined by the factors inherent in its structural organization. These may be summarized under five headings:

• The amount of cell wall substance present in a given volume of wood

• The amount of water present in the cell wall

• The proportionate composition of the primary chemical components of the cell wall and the quantity as well as the nature of the extraneous substances present

• The arrangement and orientation of the wall materials in the cells and in the different tissues

• The kind, size, proportions, and arrangement of the cells making up the woody tissue

The main physical properties of wood include: color, luster, texture, macro-structure, odour, moisture, shrinkage, internal stresses, swelling, cracking, warping, **density**, sound - electro - thermal conductivity.

Color, shine, texture and macrostructure determine the appearance of wood.

2.5.2 Mechanical properties of wood

a. Hardness

Already dealt with earliar.

b.Flexibility

Flexibility is the capacity of the wood to bend out of shape without breaking. It is the property required by the wood sieve – frames, basket work, bent wood furniture etc.

The maximum amount of flexibility is obtained in woods with long straight fibres and free from knots. Soft light woods are generally more flexible than hard heavy wood. Moisture increases flexibility while dryness decreases it. The presence of natural resin in more or less in fluid form increases flexibility. Frost reduces flexibility rendering brittle.

c. Elasticity

Elasticity is the capacity to bend out of the original shape and regain the original form and dimensions after deformation. Elasticity is the property required for carriage shaft, shoulder poles, bows, sports goods, fishing rods etc.

Elasticity is increased by length and straightness of fibres and freedom from knots, wavyness, and soundness. As a rule elasticity increases with specific gravity.

Examples of some of the more elastic woods are

i. very elastic : Grewia species
Borassus flabellifer
Anogeissus lati folia
Bamboo
Canes

ii. Elastic: Casuarina equsetifolia

Chloroxylon sweitenia

iii. Moderately elastic:

Mangifera indica
Lagerstroemia species
Tectona grandis

Modulus of elasticity is calculated using the fallowing formula.

$$\frac{\text{load (N)}}{\text{cross-sectional area (mm}^2\text{)}} = \textbf{stress (N/mm}^2\textbf{)}$$

(stress is denoted by σ)

and

$$\frac{\text{deformation (mm)}}{\text{original length (mm)}} = \textbf{strain (unitless)}$$

(strain is denoted by ε)

hence

$$\frac{\text{stress } (\sigma)}{\text{strain } (\varepsilon)} = \text{a constant}$$

$$= \textbf{modulus of elasticity}$$

d. Fissibility

Fissibility in a wood means the capacity of the wood to split in the direction of the fibres. This is an important property required for wood for split fuel, manufacture of wheel spokes, matches ,oars, carriage shafts, basket wook, matting etc.

Factors influencing fissibility are:

i. structure of the wood:

straight grained wood is more fissible (eg; Conifers, Teak etc) . Interlocked fibres difficult to split.presesne of large medullary rays increases fissibility in radial direction.

ii. Elasticity of wood.

More elastic the wood the more fissible it is when a wedge is driven in to an elastic wood, the wood on either side of the crack pressing on the wedge tend to force the fibres apart some distance in front of it, thus facilitating the work of splitting.

iii. Amount of moisture

As a rule green wood splits more easily than dry wood,

Example of fissile wood are;

a.very easy to split

Bamboo and cane

b.Easy to split

Cidrus deodara
Pinus roxburgii
Tectona grandis

c. Moderately difficult to split
Mangifera indica
Dalbergia sissoo
Albizzia labbek

d. Difficult to split
Anogeissus latifolia
Tamindus indica.

E. strength of the wood

Strength of the wood is its ability to resist external forces tending to alter its shapes. These forces , depending on the direction of application may be compressive , tensile or shearing hence the necessity of qualifying the strength in compression, tension or shear. Other things being equal strength varies with density, condition of seasoning, soundness.

Strength test

The strength in timber is determined bt various tests like bending , compression , Shear, and torsion.

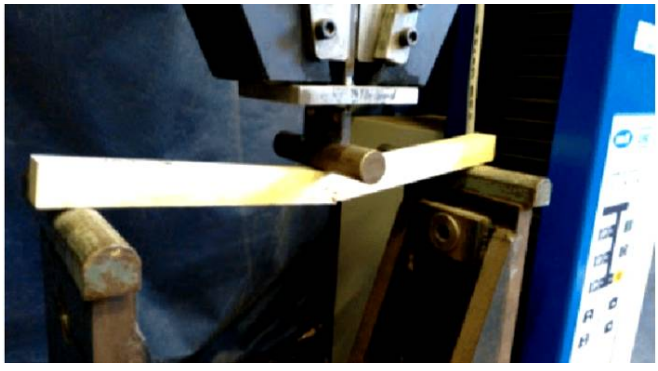
1. Bending test

The bending test or transverse strength test to find out the fitness of species for use as beam, girders, rafter etc will be conducted by applying weight on a specimen of timber of the species to be tested.

Bending test may be

i. Static bending test

specimen of prescribed dimensions (30” x 2” x 2”) is placed horizontally resting on two supports at the end and weight is applied slowly on the specimen (the specimen is loaded at the centre of the span), the loading head descend at the rate of 1/10 inch per minute and diflections correctly up to1/400 inch, simultaneously. Load deflection curve is then plotted from which strength functions are calculated.



Static bending test

ii. Impact bending test

The test piece of 30”x2”x2” is loaded as in static bending test. The load applied as blow on the test piece i.e. a blow is delivered at the mid span by a freely falling weight (50 lbs) which is raised by an electro magnet and automatically released at a predetermined height till complete failure or 6” deflection of beam (test piece) is obtained . The drop i.e. through which the load is dropped is plotted against square of deflection. As within the elastic limit (the maximum stress the timber can withstand with without injury) square of the deflection is proportional to drop, the elastic limit is indicated by the point where the straight line portion ends.

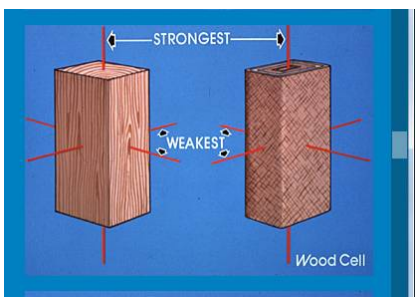
Data obtained from these tests are used to determined.

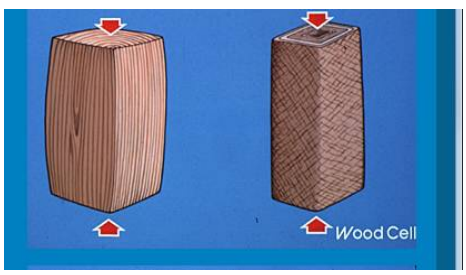
1) strength as a beam
2) Toughness and shock resisting ability
3) Flexibility and tuoghnes
4) Elaticity.

2. Compression test

i. compression parallel to the grain.(resistance to crushing parallel to the grain).

This property is required in struts, mine props, piles, wheel spokes etc. In this test the specimen tested are 2”x2” in cross section and 8” along yhe grain. Pressure is applied at the end through hemispherical bearing block. From this test compressive stress at elastic limit is computed.



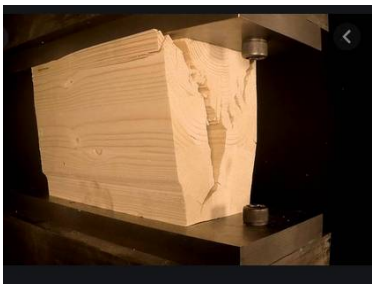


compression parallel to the grain

ii. Comprempression perpendicular to the grain.

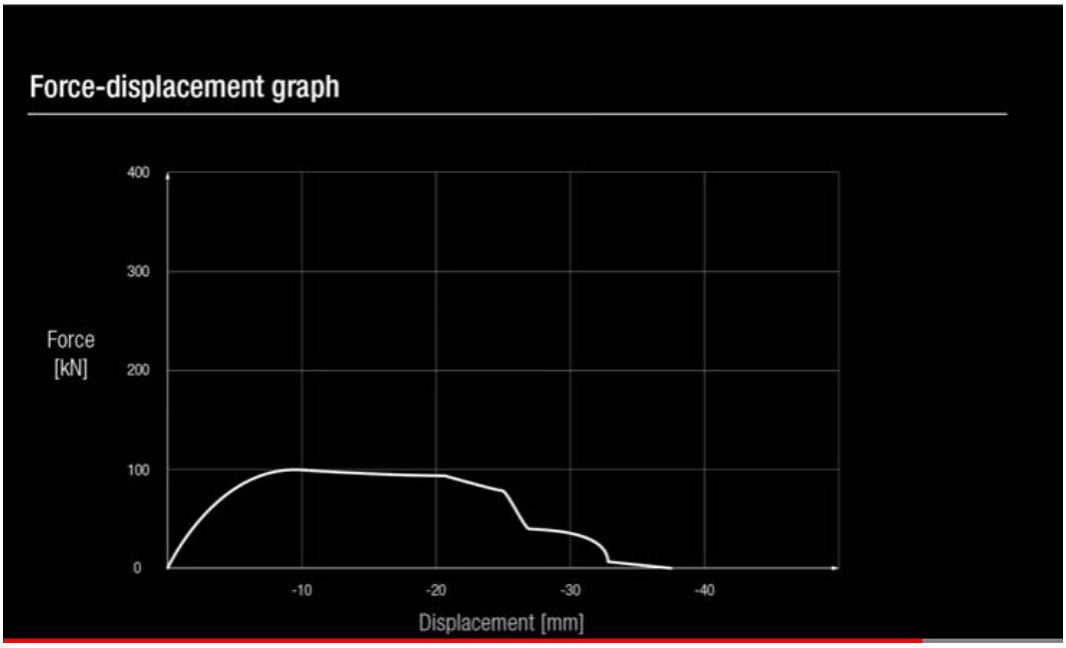
This is generally 1/4th of compression parallel to the grain in the wood. This property is requires in rollers , railway sleepers , axles, floor beam etc. The dimension of specimen tested is 6”x2’’x2”. Load is applied through a 2” wide steel plate placed across the mid length of the specimam on a radial surface. In this way fibre stress at elastic limit is determined.

On the basis of figures obtained of various test value , the relative suitability of different species for particular uses are determined taking the strength properties of Teak as standard.This is known as suitability figures and is expressed as percentage of the corresponding properties of Teak.



Perpendicular to the grain

Compressive failure of a timber block



2.5.3 Factors Affecting The Strength Of Wood

Besides the normal variability of strength among and within species, many other factors may affect the strength of wood. These factors may be broadly grouped into natural defects and irregularities, factors related to the environment and the effects of biological agents.

When the grain direction is not parallel to the long axis of a wooden component, it is said to be cross-grained (sometimes referred to as short-grained). Cross grain may occur from spiral grain in the tree or by the manner in which the timber is sawn. In linear furniture parts such as legs and spindles, whose performance depends on longitudinal properties such as bending resistance, cross grain may result in serious strength loss. A slope-of-grain of one in five, for example, may result in 50-60% reduction in the modulus of rupture. Knots in wood are another major weakening defect. Loss in strength results not only from the abnormal tissue and grain direction of the knot itself, but from the cross grain of wood distorted around the knot. Compression wood, the reaction wood formed in conifers as a result of crooked or leaning stems, is usually higher in density and compression strength than normal wood, but the wood is weaker in tensile strength and in both modulus of rupture and modulus of elasticity in bending. In hardwoods, tension wood is exceptionally weak in compression parallel to the grain though it may be stronger in tension and tougher than normal wood of the same density. It exhibits abnormally high longitudinal shrinkage and slightly increased tangential, but normal radial, shrinkage. The lignin content of the cell wall is deficient compared with normal wood and gelatinous fibres may be present.

As wood dries below the fibre saturation point, strength increases with the loss of bound water. The greatest increases are in compression along the grain: strength is approximately doubled when wood is dried to 12% moisture content, tripled when oven-dried. Modulus of rupture is increased much less, and modulus of elasticity is increased least upon drying.

Strength of wood is also affected by temperature, increased as temperature is lowered, decreased as temperature is increased. Over the range and duration of naturally occurring temperature changes, strength changes are temporary. However, if exposed to higher than natural temperatures, or for prolonged periods, permanent loss of strength may result. Effects of heat in reducing strength are least in dry air, greatest in moist air or steam. The use of steaming to temporarily plasticize wood for permanent bending of furniture parts is well known.

Strength of wood is also related to duration of loading. Time-related creep in wood reduces strength over longterm load periods. For example, a beam might carry a short-term (5 minutes.load three times as great as it could carry for a long term (a hundred years or longer.

The destructive effects of wood-inhabiting insects such as termites, carpenter ants and beetles need little elaboration, as the physical loss of wood will result in proportional loss of strength. Fungi are a major cause of deterioration in wood. In order for the threadlike hyphae of fungi to develop in wood, four major requirements are necessary: favourable temperature (70-85 °F is ideal), oxygen (20% or more air volume in the wood), moisture (fibre saturation point or above is ideal), and food. Wood-staining fungi utilize the residues of stored materials in parenchyma cells of sapwood but they do not attack cell walls. Therefore, although the staining fungi discolour the wood, they do not reduce its strength. However, the wood-

destroying fungi utilize enzymes to break down and assimilate the cell wall substance, producing various forms of decay or rot. Initial stages of fungal invasion, termed incipient decay, may at first have insignificant effect on strength. Impact strength is the first strength property to be affected. If allowed to continue, total loss of strength may result. It should be noted that Chlorociboria both deposits a green stain in the wood and causes losses of strength. Controlling moisture is the principal approach to preventing decay. If wood is maintained below 20% moisture content, decay fungi cannot develop.

2.5.4 Suitability indices and their use

2.5.5Safe working stress and their and their valuation

safe working stresses and their valuation:

Safe working stresses for timber are derived both from tests of small clear specimens which afford average values of the inherent strength of the different species, and from tests of large timbers which

- The determination of a safe working stress then involves the adjustment of test values to meet the conditions of use.
- This adjustment requires
- (a) consideration of the loss in strength from defects,
- (b)the effect of long-continued loads,
- (c) the variability of individual pieces from the average, and
- (d) the possibility of slight accidental overloading.

PERMISSIBLE STRESS

- Grouping - Species of timber recommended for constructional purposes are classified in three groups on the basis of their strength properties, namely, modulus of elasticity (E) and extreme fibre stress in bending and tension along grain .
- The characteristics of these groups for Grade 1 structural material are as follows: (IS : 3629 – 1986)

GROUPS	**MODULUS OF ELASTICITY(E) N/mm2**	**LIMIT(ft)**
A	Above 12600	18
B	Above 9800 and up to 12600	12
C	Above 5600 and up to 9800	8.5

NOTE - These groups were earlier referred to as super, standard and ordinary. Generally timbers above 0.65 Specific gravity fall under Group A, between 0.50 and 0.65 fall under Group B and those below 0.50 fall under the Group C

FACTORS OF SAFETY TO BE APPLIED TO BASIC STRESS TO OBTAIN SAFE PERMISSIBLE STRESS

SL.NO	TYPE OF STRESS	GRADE 1 LOCATION		
		INSIDE	OUT SIDE	WET
1	Extreme fibre stress in beams for broad leaved species,	5	6	7.5
2	Extreme fibre stress for beams in conifers,	6	7	8.5
3	Shear along grain	7	7	7
4	Horizontal shear in beams	10	10	10
5	Compressive stress parallel to grain,	4	4.5	5.5
6	Compressive stress perpendicular to grain	1.75	2.25	2.75

CONDITION.

a) The timbers should be of high or moderate durability and be given suitable treatment where necessary. They may be used on any location. If the location is inside and not incontact with the ground, low durability timber may be used after proper seasoning and preservative treatment.

b) The loads should be continuous and permanent and not impact type.

2.5.6 Testing and evaluation of timber products

- Each product undergoes a different set of testing. Particle board, for example, is tested for strength, hardness and flex, in accordance with prescribed slandered specification These tests ascertain that the particle board meets the expected properties .

- First, the quality control experts pull boards off the production line every two hours to perform a quick “hot” test for modulus of rupture (MOR) and internal bond (IB). MOR determines how much force it takes to break the material, while IB is a test of how much force it takes to pull the material apart.

- Once the material is sanded and ready to ship, quality assurance technicians pull a sample to conduct a full test. This includes MOR and IB tests but may also have a modulus of elasticity test to see the level of flex the material presents. Other tests

measure linear expansion, moisture content, hardness, and thickness for underlayment.

An X-ray machine lets techs examine the density of the particle board and make determinations on where the peak densities are located.

2.5.7 Classification of defects of wood

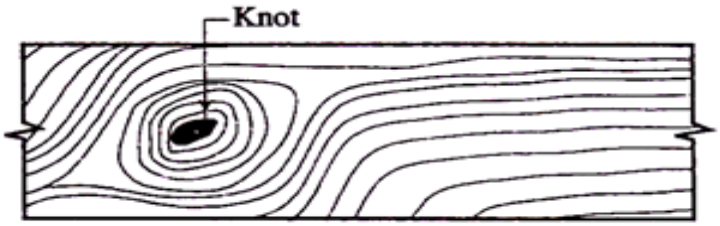
Defects in wood includes all abnormal conditions which permanently reduces its utility.They may be caused by

- 1. abnormal growth
- 2. rupture of tissues
- 3. wounds.

Defects due to abnormal growth

a) Knots

Knots are portions of branches which have enclosed in the wood of the tree stem. The cross section of knot is usually circular or oval in shape.



Knot

i) Live or sound knot.

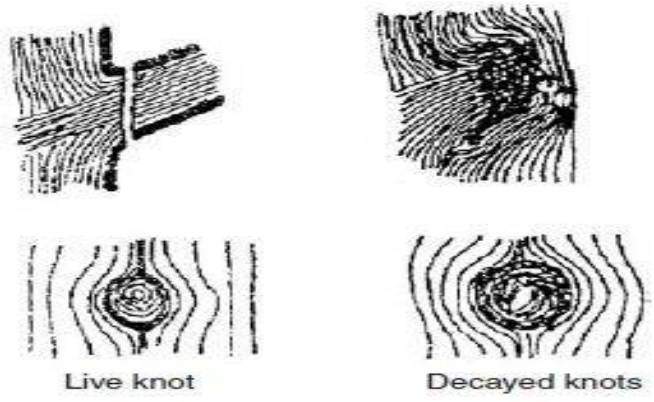
A knot at least as hard as surrounding wood to which it is firmly attached. It show no indication of decay, and it is darker in colour than surrounding wood. Live knot do not come of when the wood dries and are not a serious defect, though in some cases these knots provide access to fungi in the crevices..

ii). Loose and hallow knots.

A knot which has fallen out and is likely to fall out , leaving a hole free from decay. Presence of loose and hallow knots weaken the timber strength. They may fall out of sawn board.

iii). Decayed or unsound knots

A knot rendered softer than surrounding wood by decay. If the decay is advanced , there may be a hole in the centre of the knot and the sides of the knot show a sign of decay.



- Live or sound knot in some broad leaved species some time enhance the value of the timber by giving decorative appearance such as in Teak, Sissoo etc. when these are not considered as defects.Knots are objected to railway sleepers especially at spike points.
- Knots in timber can be reduced by growing dense canopied woods in which trees have no opportunities of sending out large side branches.

b). Twisted fibre.

- Twisted fibre is the result of the wood proceeding upwards in a spiral manner instead of in a true vertical direction. The twist may be from right to left or left to right. The

former being most common. Trees with twisted fibre can be recognized by a corresponding twist in the bark visible externally.

- Wood with twisted fibre is not suitable for sawing in to planks. It is also unsuitable for any purpose where straight split wood is required .In large beam it is not a serious defect. Twisted poles and post are however stronger than straight grained pole.

c). Wavy wood and burrs

- Waviness is a character of of certain species in which fibres grow in a wavy manner instead of true vertical line or presence of several latent buds may give raise to wavy course of fibre. It is not a serious defect. On the other hand it enhance the value of the wood by increasing the beauty of the grain.

- Burrs are concentrated masses of wood with excessive waviness. They are usually formed by bifurcating and growing individually in concentric layers which eventually form knoty swelling on the out side of the stem. They are due to injuries in many cases when the tree was young so that dormant bud unable to develop in to normal branches and produced mass of contorted tissues.

- Burrs are technically defects in wood, but they are very valuable for exceptionally fine figured wood they yield on sawing. *Albizzia labbek, Terminalia tomentosa* yield fine figured decorative burrs which are very much in demand high class cabinet making.

d). Constriction due to climber

Climbers which will twine round the stem of the tree can influence the shape and development of trees considerably by controlling the growth of the stem there by making them practically useless for commercial purpose.

- As the tree grows the climber unable to loosen it self from the tree and the climber is forced to tighten against the stem and embedded when the stem grows further resulting formation of deep groove running from bottom to top.eg. of climber causing constriction on stem *Bauhinia vahlii* .

2. Defects due to rupture of tissues

Wood shrinks when it dries and this shrinking causes a rupture of tissues resulting in splits and cracks. These rupture, known as shakes, are definite defect in wood. Shakes may be

i) . Heart and star shakes
ii). Radial shakes and
iii). Cup and radial shakes

i). Heart shakes

A simple heart shake consist of a crack starting from pith and extending out wards to wards the periphery in a radial direction. When there is only one crack ,which extend right across the pith in the opposite direction. It is termed heart shake.

If there are more than one such cracks radiating from the pith the defect is known as compound Heart shake or star shake.

Heart shakes are generally caused by the rapid drying of centre tissues of the stem round the pith. This may be brought about by these tissues having dried out to certain extent while the tree was still standing, owing to shortage of water supply .very old tees and trees growing in unfavourable soil condition are liable for such defects. Heart shake may also be caused by shock of another tree falling, by the action of wind or the tree itself is felled. after falling these cracks continue to extend.

Simple heart shake does not reduce the value of the tree much on conversion in to sawn timber as the cut may be made through the crack. Such log is unfit for ply wood and veneer industries.Heart shakes are vry common in very old trees of *Tectona grandis ans Anoguisses latifolia.*

Star shake Cup/ring shake Radial shake

ii). Radial shakes

Radial shakes are the cracks connecting from outer side of the stem and extending radially inwards. they are caused by the shrinkage of outer tissues at a greater rate than the inner tissues resulting in a rupture of periphery , and formation of cracks and extend inwards. It ma bre due to action of frost in which case it is known as frost crack.

Radial shake may also occur due to sudden excessive heat by hot sun followed by a cold night. It may be due to forest fire also.Rupture formed will be aggravated by strong wind. Trees which split radially are more liable to radial crack.

iii). Cup and ring shake

Cup and ring shakes are formed when the rupture fallows the direction of the annual rings. When the rupture extend only a part of the way round it is called cup- shake. If it extend the whole way round it is called a ring- shake complete ring shake are not very common.

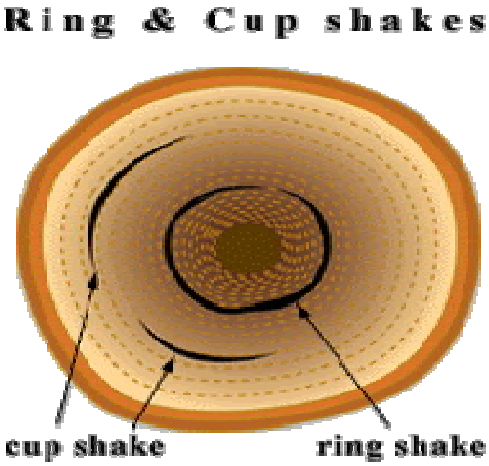
Cup and ring shakes may be caused by the shrinkage of the central tissue sowing to loss of moisture , action of frost, fire or other forms of injury to the cambium or by shock

produced when the tree sways during high wind or due to concussion when another tree falls against it or when the tree itself falls.

Cup shake may fallow complete defoliation by caterpillars, giving a severe check to the nutrition of the tree, where by new wood fails to adhere to that of previous year.some times it is caused by fungus attack where the mycelium spread up the cambium.

The effect of cup and ring shakes on the utility of the log depend to a large extent on the size, number and portion of the shakes and on the purpose for which wood is required.

Cup shakes are mechanical defect inherent in the wood prior to felling and there is no real remedy. They can be aggravated by real rough handling of log and by too rapid drying.



3. Defects result from wounds

i). Pruning

The new wood which grows over the cut never joins with cut surface. This is a defect which weakens the timber strength. The pruned surface is also a point for entry to fungi and insect and there may result in a deterioration of the wood .

ii). Occluded broken branches

The defect is similar to the one of of pruned branches but more serious, as when a branch is broken off the broken surface present better opportunity for fungi to develop. Broken branches also result in loose knots being formed and these, if numerous, are a serious defect in any wood.

iii). Rind galls

These are defect in timber due to inclusion with in the wood of old healed wounds which may caused by a variety of circumstances such as passing carts, falling trees , debarking by deers and other animals etc..

During the process of healing rot is liable to enter the wound and spread inward, while the new wood over the wound does not join completely with the old wood, thus producing a defect which may be discovered only when the timber is sawn.

iv). Fire

The damage resulting from fire usually consisting of a scorching of bark . If the cambium layer is damaged a definite rupture between the old wood and any wood ,that may form,occurs and if the damage is complete around the base of the stem , the tree will usually die.

4. Defects due to the attack of insects and parasitic plants

i). Insects

Damage to wood by insects may result in a serious defects in the wood from commercial point of view. They destroy large quantities of timber by tunnelling the wood.these insects may be divided in to classes according to their mode of attack

a). Insects which bore into living trees to lay their eggs and pupate.

Against these successive preventive measures are difficult.some of the most destructive such insects are " bee-hole borer" of teak, Stromatiun species, a longicorn beetle which in to the heart wood of Sandal wood tree and Apate jesuita , a beetle which bore in to casuarinas stem and Hoplo cerambix spinicornis, a major borer which attack Sal trees.

b). Insect which bore in to dying or dead trees.

Such insects may either lay their eggs in the barks or bore in to the wood to lay their eggs. Among the most important of these insect are shot- hole and pin-hole borer, longicorns, weevils and power post beetles.

Bamboo are subject to attack by boring beetles. The most common insect in this respect shot-hole borer (Dinoderus species) commonly known as ghoons which riddle bamboo culms within few months of felling.

Termites in Timber

Termites also known as white ants which forms a colony inside the timber and eat the core part of the timber rapidly. They do not disturb the outer layer of timber so one cannot identified their presence. The trees in tropical and sub-tropical regions are mostly affected by these termites.

However, some trees like teak, Sal etc. cannot be attacked by termites because of the presence of termite preventing chemicals in their cellulose part.

Beetles in Timber

Beetles are a type of insects which destroy the sap wood of the tree and makes a tunnel like hole from the bark. Usually the diameter of hole is around 2 mm. They convert sap wood into powder form and these holes are used by larvae of these beetles.

Almost all hardwood trees can be prone to damage by these beetles

Marine Borers in Timber

Marine borers are usually found near coastal areas. They do not consume wood but they make large holes of diameter up to 25mm in the timber to live inside it. They excavated up to 60mm deep in the wood.

The wood attacked by marine borers is of less strength and discolored. They can attack all types trees present in their region.

Parasitic plants.

Parasitic plants do damage to the trees by sending in haustotia , or root like growth which penetrate the wood there by producing holes in the wood of their and rendering it useless as timber.

Unsoundness

The defect of unsoundness is due to the action of fungi , whose hyphae penetrate into the wood and break down the tissues causing rot which is popularly known as red-rot or white – rot depending of its colour. These fungi may find access through wound in the bark, through the roots, or at place where branches were broken off.

2.5.8 Measurements and evaluation of defects in wood

- Ultrasonic scanning experiments were conducted for detecting defects in wood pallet parts using rolling transducers..
- Sound and unsound knots, bark pockets, decay, splits, holes, and wane were characterized using several ultrasonic parameters.
- Each ultrasonic waveform collected was characterized using eight ultrasonic variables - three involving time of flight, two involving ultrasound pulse energy, one using ultrasound pulse duration, and peak frequency.
- The amplitude of ultrasound signals was significantly reduced by defects. The degree of dispersion of the power spectrum mostly depends on the severity and type of defects.
- The energy loss parameters are more sensitive to defects compared to time of flight measurements
- . Unsound knots, bark pockets, decay, holes, and splits are easily detectable and distinguishable using power spectrum,
- Energy loss, and peak frequency parameters. Two-dimensional images were constructed from multi-line scanning data for each sample.
- The constructed images are able to show the exact location and area of the defects.
- Scanning properties of this proto- type system suggest that an on-line system to inspect, sort, and grade wooden pallet parts is possible using rolling transducer ultrasonic inspection.

2.6 wood seasoning

2.6.1 Introduction:

Wood drying (also seasoning lumber or wood seasoning) reduces the moisture content of wood before its use. When the drying is done in a kiln, the product is known as kiln-dried timber or lumber, whereas air drying is the more traditional method. Seasoning is the process of removing the moisture content from wood to minimize structural problems when used in construction or to provide less smoke and more uniform combustion when used as firewood. There are two main ways of seasoning timber, Natural (Air) and Artificial (Kiln) drying. Both methods require the timber be stacked and separated to allow the full circulation flow of air, etc. around the stack. Air seasoning is the method used with the timber stacked in the open air.

Definition:

The process of removal of moisture content from wood, so as to make it useful for construction and other uses, is called drying of wood or seasoning of wood. This reduces the **chances of decay**, improves **load bearing properties**, **reduces weight**, and exhibits more **favourable properties** like thermal & electrical insulation, glue adhesive capacity & easy preservative treatment etc. Seasoning of Timber is a process by which moisture content in a freshly cut tree is reduced to a suitable level. By doing so the durability of timber is increased.

WOOD MOISTURE CONTENT (WOOD MC)

Water trapped inside the wood exists in two different forms: free water and bound water.Free water is distributed in inter-cellar space. Since it is not chemically connected to wood structure, it can be relatively easy removed. Bound water is located in cell walls and is connected to wood fibre by molecular forces. This is the reason why it is much harder to remove bound water than free water from the wood. It can be removed only through evaporation process.

It is determined that part of water (moisture) content in the wood above 30% is free water. Below this level of 30% wood only contains bound water. This 30% border is also known as point of saturation of wood fibres.Water in wood is known as Wood Moisture Content (MC) and is represented in %. It is a ratio of weight of water inside the wood and absolutely dry wood:

If we say that wood moisture content is 10%, it means that in peace of that wood which would weight 1000 g when absolutely dry there is 100 g of water. Moisture content of raw wood depends on the type of wood and can reach 200%. Average values are in range 50 - 100%.

Depending on the application of the wood, it should be dried to certain MC:- plywood:5 - 8% , parquet:8 - 10%- room furniture8 -10%- garden furniture13 - 16%- joinery:10 - 12%

Moisture Content (MC) of the wood can be determined using the formula

2.6.2 Object of seasoning

1. To impart hardness, stiffness, strength and better electrical resistance to the timber
2. To maintain the shape and size o the component of the timber article which expected to remain unchanged in form
3. To decrease the weight of the timber and thereby reducing the cost of transport of timber
4. To make timber easily workable and to facilitate operations during conversion
5. To make timber suitable for receiving treatment of paints
6. To make timber safe from the act of fungi and insect
7. To make suitable for joinery works
8. To reduce the tendency of timber to crack, shrink and warp

Importance of seasoning

Seasoning. **Seasoning timber** is essentially just to drain it of water which is called its moisture content. This can cause it to shrink but it helps to prevent warping, splitting, it will become lighter and stronger and it becomes easier to machine.

Seasoning method.

Based on the recommendations of IS : 1141-1973 the seasoning methods should be classified as : Air seasoning or natural seasoning, and Kiln seasoning or artificial seasoning.

2.6.3 Air Seasoning

As soon as possible after felling, the log is converted by sawing it into battens and planks etc. These are then stacked on a well drained place in the shade. While stacking care should be taken to ensure free circulation of fresh air all around each piece .

In the Air Seasoning Unseasoned wood exposed to the open air but protected from rain will gradually dry out until it achieves a moisture content which is in equilibrium with the surrounding air. Air seasoning is done by stacking the timber exposed to the atmosphere either in the open or in a shed.

In air drying, there are two essentials which control the final condition and dried quality of timber that has been stacked for drying. The first of these is to maintain sufficient air movement throughout the yard and through individual stacks to ensure uniform drying. The second is to use stacking techniques which will ensure that degrade due to warping, twisting, checking, etc. is kept to a minimum. *Stacking for air drying of timber is done in several ways.*

Process of air seasoning timber logs are arranged in layers in a shed. The arrangement is done by maintaining some gap with the ground. So, platform is built on ground at 300mm height from ground. The logs are arranged in such a way that air is circulated freely between logs. By the movement of air, the moisture content in timber slowly reduces and seasoning occurs. Even though it is a slow process it will produce well-seasoned timber.

$$\%MC = \frac{(Wet\ weight\ ) - (Oven - dry\ weight\ )}{(Oven - dry\ weight\ )} x\ 100$$

Advantages of natural seasoning The moisture content of wood can be brought down to about 10 to 20 percent. It does not require skilled supervision.¬ For thicker sections artificial seasoning is uneconomical where natural seasoning can be adopted. This method is cheap and simple

Disadvantages of natural seasoning 1.Less control over air 2.The drying of different surfaces may not be uniform 3.Chance of attack of fungi and insects during seasoning.

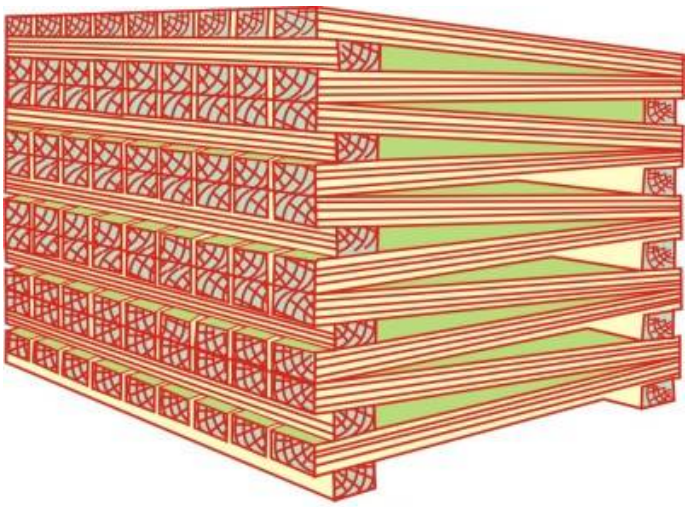
This process of seasoning timber is the best as it gives very strong and durable timber, but it is extremely slow. It takes more than six months for timber to season in moderate climates. Care should be taken not to expose the freshly converted timber stacked for seasoning to severe winds or to sun.

This process of seasoning timber is the best as it gives very strong and durable timber, but it is extremely slow. It takes more than six months for timber to season in moderate climates.

Proper stacking of timber while seasoning will ensure the timber free from seasoning defects Methods of stacking.

The one and nine methods of stacking sleepers

Timber, before seasoning, should be stacked in yards free from weeds and debris. The yard should have big shady trees to protect the timber from direct sun.



The one and nine methods of stacking sleepers

Ends of logs should be protected against splitting by applying anti-splitting compositions and stacked on foundation in closed stacks in one or more layers. Stacks should be protected against direct sun by providing a covering – if needed.

The one and nine methods of stacking sleepers is best suited for moderately heavy conferous sleepers in hot climate and for heavy timbers in moist climates.

Close Crib method

In the close Crib method reduced air circulation slows down the pace of seasoning.

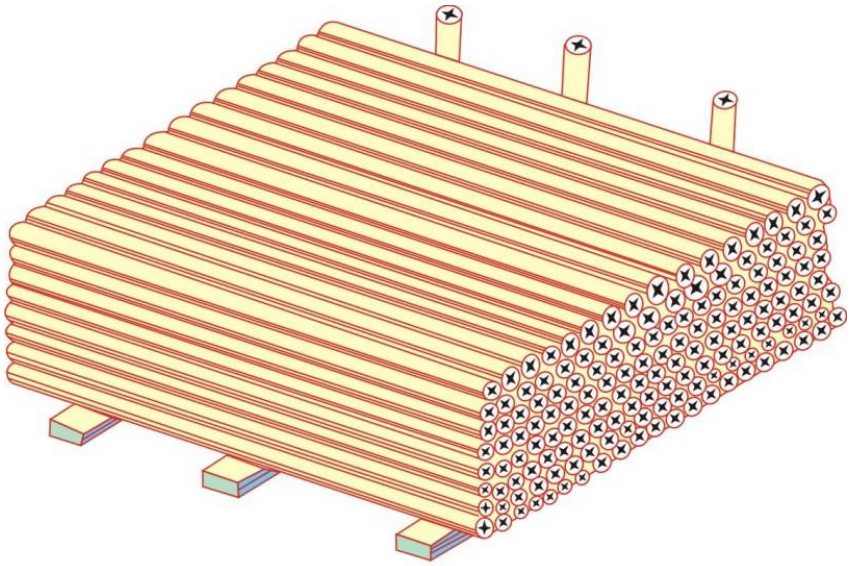
Close Crib method

This method is recommended for stacking heavy structural timbers like sal in hot and dry localities.

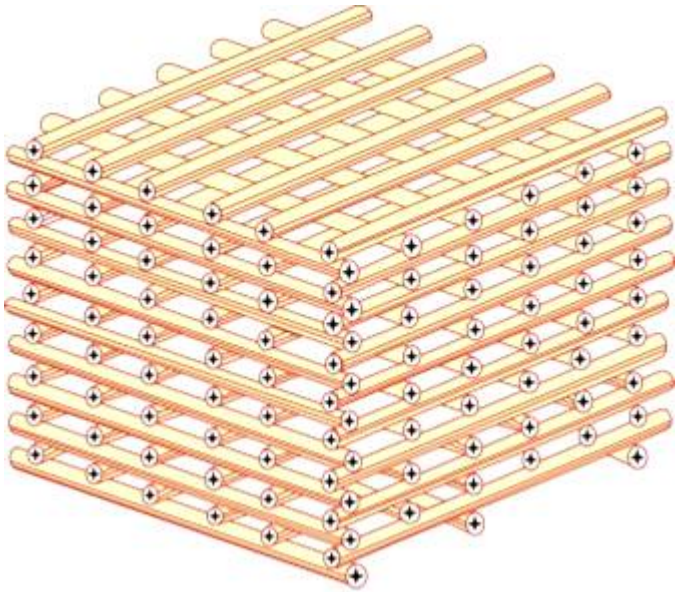
Open Crib method

Open crib method

Open crib method is a modification of the close crib method and because of more air circulation taking place it is more akin to the one and nine method in its effects. Stacks of not more than 100 sleepers are recommended. Poles are stacked either in closed heaps or with crossers. If stacked in closed heaps then there should be alternate layers of butt ends and of top ends so that the two ends of the stack are level. Poles themselves could be used as crossers, which should not be spaced more than three metres.



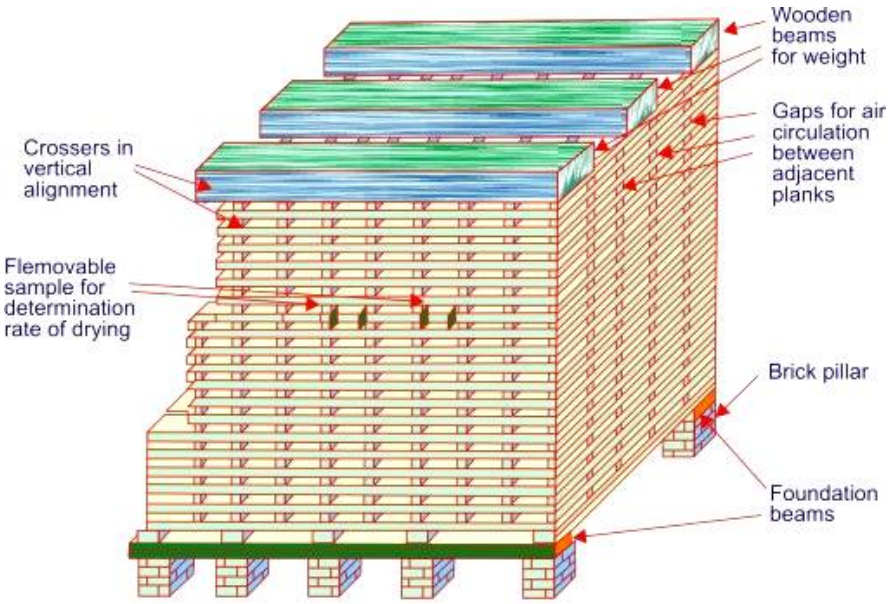
Fence posts should be stacked in open crib fashion in which successive layers of posts are at right angles to each other and there is a gap of about 8 cm between adjacent posts in the same layer. Centre to centre distance between crossers should not exceed 1.5 m and the height of stack should not exceed 3 metres.



Horizontal stacking of sawn timber is done on vertical pillars of treated timber, brick masonry or of cement concrete 30 cm square in section and 30 to 45 cm high. The pillars are spaced 1.2 m centre to centre along the length and the breadth of the stack. The length of material to be stacked decides the length of stacking unit. Long beams of cross section 10 cm × 10 cm and above are placed on the foundation pillars to form a frame work for stacking timber. These beams should obviously be from strong timbers.

Scantling and squares should be stacked with crossers 5 cm × 4 cm in section and spaced 2.5 to 3 m apart. The ends should be protected with moisture proof coatings.

Planks should be stacked on level platform with crossers of uniform thickness and section, which (the crossers) should be in vertical alignment in a stack . Longer planks should form the bottom of the stack and the shorter one's the top. Heavy wooden beams should be placed on the top to prevent top layers from warping. A gap of about 2.5 cm should be left between adjoining planks for free circulation of air in the centre of stack. The stack should be protected against rain and sun by providing a shed over it.



2.6.4 Kiln seasoning or artificial seasoning.

Artificial method of seasoning or kiln seasoning speeds up the seasoning process. For large scale production of seasoned timber kiln seasoning is a must.

Kiln seasoning is done in a chamber equipped with arrangements for heating and humidifying the air to required conditions of relative humidity and temperature and for its circulation across the timber stacked in the chamber for seasoning. Usually it is steam that it used for heating and humidifying the air in the kiln. The seasoning of the timber is started at a comparatively lower temperature and high humidity. As the timber dries these conditions are gradually altered until at the end of the seasoning the temperature of the air inside the chamber is fairly high and the humidity is low. The kiln charge is allowed to cool inside the kiln to within 15 to 20ºC of the outside temperature before removal. Seasoning of timber by this method takes about four to five days under normal conditions.

Significant advantages of conventional kiln drying include higher throughput and better control of the final moisture content. Conventional kilns and solar drying both enable wood to be dried to any moisture content regardless of weather conditions. For most large-scale drying operations solar and conventional kiln drying are more efficient than air drying.

Compartment-type kilns are most commonly used in timber companies. A compartment kiln is filled with a static batch of timber through which air is circulated. In these types of kiln, the timber remains stationary. The drying conditions are successively varied according to the type of timber being dried. This drying method is well suited to the needs of timber companies, which have to dry timbers of varied species and thickness, including refractory hardwoods that are more liable than other species to check and split.
The main elements of chamber drying are:

Construction materials

The chambers are generally built of brick masonry, or hollow cement-concrete slabs. Sheet metal or prefabricated aluminium in a double-walled construction with sandwiched thermal insulation, such as glass wool or polyurethane foams, are materials that are also used in some modern timber ovens. However, brick masonry chambers, with lime and (mortar) plaster on the inside and painted with impermeable coatings, are used widely and have been found to be satisfactory for many applications.

Heating

Heating is usually carried out by steam heat exchangers and pipes of various configurations (e.g. plain, or finned (transverse or longitudinal) tubes) or by large flue pipes through which hot gases from a wood-burning furnace are passed. Only occasionally is electricity or gas employed for heating.

Humidification

Humidification is commonly accomplished by introducing live steam into the kiln through a steam spray pipe. In order to limit and control the humidity of the air when large quantities of moisture are being rapidly evaporated from the timber, there is normally a provision for ventilation of the chamber in all types of kilns.

Air circulation

Air circulation is the means for carrying the heat to and the moisture away from all parts of a load. Forced circulation kilns are most common, where the air is circulated by means of fans or blowers, which may be installed outside the kiln chamber (external fan kiln) or inside it (internal fan kiln).

Throughout the process, it is necessary to keep close control of the moisture content using a moisture meter system in order to reduce over-drying and allow operators to know when to pull the charge. Preferably, this in-kiln moisture meter will have an auto-shutoff feature.

COMPARISON OF AIR SEASONING AND KILN SEASONING

Relative merits and demerits of the two methods of seasoning are as follows:

Air seasoning	Kiln seasoning
1. It is a slow process.	1. It is a quick process.
2. It is simple and economical.	2. It is quite technical and expensive.
3. Air seasoned timber is more amenable to attacks of insects and fungi.	3. Kiln seasoned timber is less amenable to attack of insects and fungi.
4. It requires more stacking space.	4. It requires less stacking space.
5. It gives stronger timber.	5. A little weaker timber is obtained.

2.6.5 Special method of seasoning

Water Seasoning

Water seasoning is the process in which timber is immersed in water flow which helps to remove the sap present in the timber. It will take 2 to 4 weeks of time and after that the timber is allowed to dry. Well-seasoned timber is ready to use.

Seasoning by Boiling

Seasoning of timber is also achieved by boiling it in water for 3 to 4 hours. After boiling timber is allowed to drying. For large quantity of timber boiling is difficult so, sometimes hot steam is passed through timber logs in enclosed room. It also gives good results. The boiling or steaming process develops the strength and elasticity of timber but economically it is of heavier cost.

Chemical Seasoning

In case of chemical seasoning, timber is stored in suitable salt solution for some time. The salt solution used has the tendency to absorb water from the timber. So, the moisture content is removed and then timber is allowed to drying. It affects the strength of the timber.

2.6.6 shedule and classification of timber.

Already dealt with in 1.5

2.6.7 Design of seasoning kil

Design and Operation of a Solar-Heated Dry Kiln

Roof Design

This design is very similar to a solar greenhouse. A passive solar collector provides the kiln's drying heat, which is generated from the sunlight that passes through the roof and strikes a solar collector inside the kiln. Many factors affect how much heat can be obtained from the sunlight. One is the slope of the roof, which in this design is a 45-degree angle to the south. The optimum roof angle is dependent on your location and is typically equal to the latitude of your location. One difficulty in choosing the optimal roof angle is that the optimal angle for solar collection changes with the season since the angle of the sun changes. If you are planning on operating your kiln during the winter months, you can improve your collector's performance by increasing the roof angle another 10 degrees. For example, Blacksburg, Virginia, has latitude of 37 degrees; therefore the optimum angle for winter operation would be 47 degrees. We compromised with a 45-degree angle to make construction easier.

The type of transparent roofing material, or glazing, can also affect the amount of heat energy collected from the sun. The glazing must transmit sunlight through to the solar collector and not reflect it. It must also have some protection from degradation by the sun's ultraviolet rays. Many different glazings are possible, including glass, polymer plastic films, and fiberglass panels (see References for information on the different types of glazings). This

kiln uses greenhouse rated corrugated polycarbonate known as Tuftex purchased from the local building supply store. For winter operation or cooler climates, it is best to use two layers of clear roofing. The layers are separated by 2 x 4 materials to help to insulate the solar collection area (Figure 1). The roof is framed with fairly wide on-center spacing, which may have to be adjusted to accommodate the width of the covering material and any anticipated snow loads.

The most critical design feature of this dryer is that there is one square foot of collector (i.e., one square foot of sloped, clear roof) for each ten board feet of 1-inch lumber in the dryer. This ratio provides the perfect amount of heat for 1-inch oak, but may provide too much heat for 2-inch or thicker oak or too little for pine or other fast-drying woods. Oak is one of the more difficult drying woods because if it is dried too rapidly, it will crack and check and if dried too slowly, the sapwood may stain and discolor. In general, thicker lumber should be dried more slowly than thinner lumber.

The collector area can be increased to provide more heat (for easier drying woods than oak) by extending the roof southward, accompanied with a shorter south wall, or simply loading less material in the kiln (This would increase the collector-to-board-foot ratio). To provide less heat with the same collector, reduce the collector area by covering part of the roof with plywood or other opaque material.

Basic Box Design

The kiln is constructed using standard framing techniques. The first step is to construct the floor with 2 x 6s, 16 inches on center. The lumber used for the floor should be preservative treated to prevent rot since it will be close to or in contact with the ground. Next, install paper-backed fibreglass batt insulation between the framing members (Figure 2). Cover the top of the batt insulation with a sheet of 0.6-mm plastic to prevent condensation. Finish the floor by placing exterior grade 3/8-inch plywood across the joists. Next, construct the walls of the kiln using 2 x 4 materials, batt insulation, and exterior-grade 3/8-inch plywood on both the interior and exterior of the frame. The plywood inside the kiln was painted with two coats of black rubber-based concrete sealer, which when dry, acts as a vapour barrier and black solar collector. Another option would be to paint two coats of aluminium paint for vapour barrier and then a third coat of black paint to absorb the solar energy. Some examples of sealers are shown in Figure 3.

The exterior is painted with an exterior grade paint to prevent weathering. Be careful not to use a vapour barrier like aluminium paint on the exterior, since any moisture that might migrate into the walls will not have a way to escape to the outside. For this same reason, paper-backed insulation rather than foil-backed insulation is suggested.

The current design has large doors at the rear of the structure for loading, unloading, and checking kiln samples (Figure 4). Previous versions of the dryer had two access doors at each end (east and west walls) to permit periodic examination of the lumber and measurement of moisture content. The previous version also had a roof hinged to the north wall and the south wall hinged to the floor. This permitted the roof to be raised and south wall lowered to facilitate loading and unloading. You may wish to add these features to the current design.

Regardless of the design, vents should be added to the north wall. The vents can be as simple as framed openings with a small piece of plywood to cover the vent when not needed or you can purchase a commercial vent similar to those used for basement and crawlspace ventilation.

The three fans used in this design are inexpensive, three-speed window fans with plastic blades (Figure 5). The fans are fastened to the roof framing about 18-inches in front of the north wall with a plywood shroud or baffle around them extending downward 3 feet below the roof and running the full length of the dryer in order to force the air through the lumber pile (Figure 6). Be careful that whenever the kiln is left empty that you do not leave the doors completely closed since the temperature of an empty kiln can exceed 200˚F, which can damage the plastic fan blades.(Source - Brian Bond, Assistant Professor and Extension Specialist, Department of Wood Science and Forest Products, Virginia Tech)

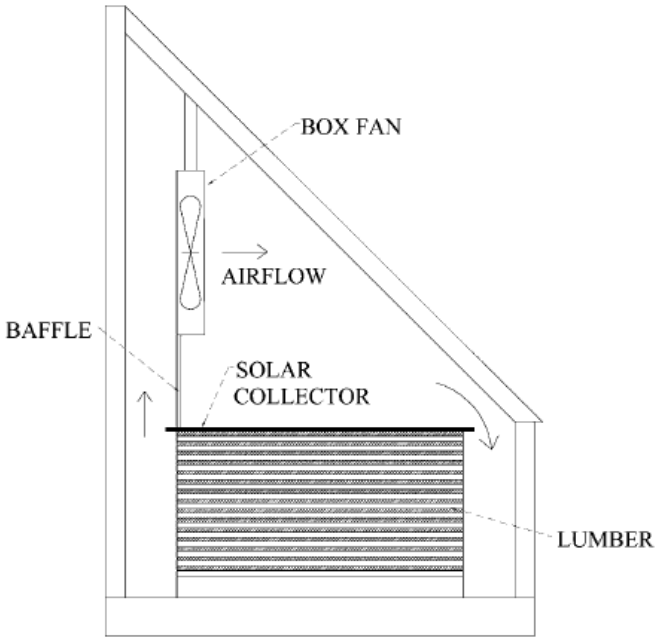


Diagram of solar kiln showing fans, baffle, solar collector, and airflow spacing between lumber and walls of kiln.

Rear view of kiln showing access doors

Solar kiln Engineering

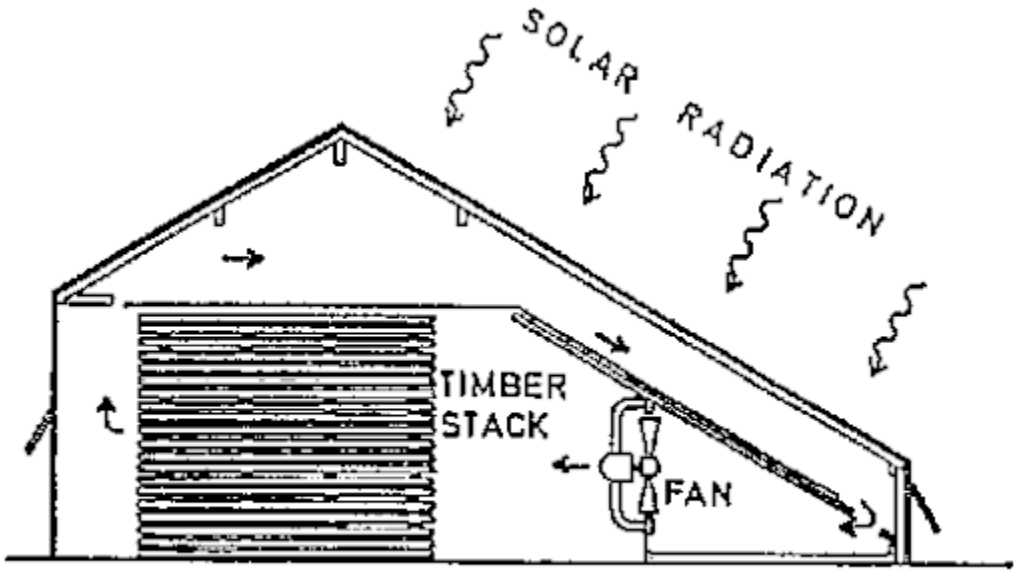


DIAGRAM SHOWING THE AIR FLOW AROUND THE KILN

Solar Timber Seasoning Kiln which is based on thermal circulation of air. It is calculated, for example, that the amount of water available to season 2.7m^3 of wood, from 60 per cent to 10 per cent moisture content, is 686kg and the heat required to evaporate the water would be 350115K cal at 50°C. The kiln designed has a floor area of 12.9 square metres and is constructed mainly with transparent glass sheets. The heat input through the walls of the seasoning chamber is calculated as 2759.38 watts. A black galvanized iron sheet of about 4 square metres is used as the solar energy collector and is fixed in the bottom of the south wall of the kiln at an angle of 30°. The collection of heat at the collector is calculated as 488 watts with its efficiency as 54 per cent. To provide a stack effect inside the chamber, a chimney is fixed vertically at the roof.

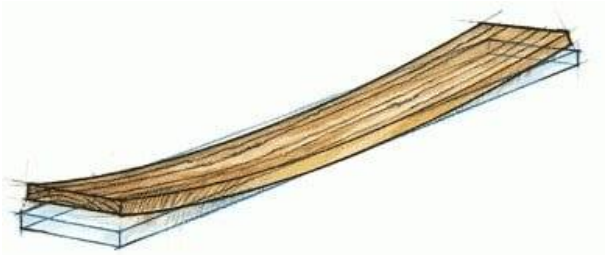
2.6.8 Air drying shed

Seasoning defects

During seasoning wood looses volume and shrink while if it is placed in water or in moist atmosphere it swells by absorption of water. Being a heterogeneous substance composed of cells of different structure and size of wood has a very variable shrinkage. Shrinkage and swelling varies in different plans in the same specimen. It is negligible in longitudinal direction (along fibre) and maximum along the tangential direction. Following defects may emerge after seasoning

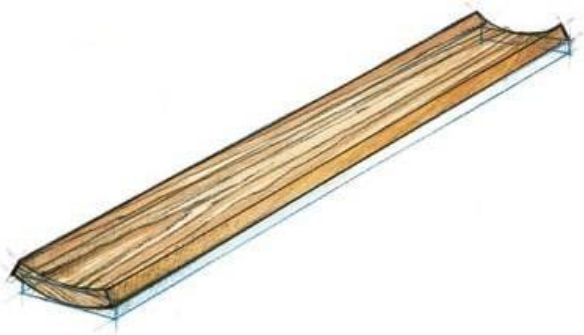
1. Bow

When the converted timber is stored for longer time, some timber planks may have curve along its length which is known as Bow.



2. Cup

If the timber planks are curved along its width then it is called Cupping of timber.

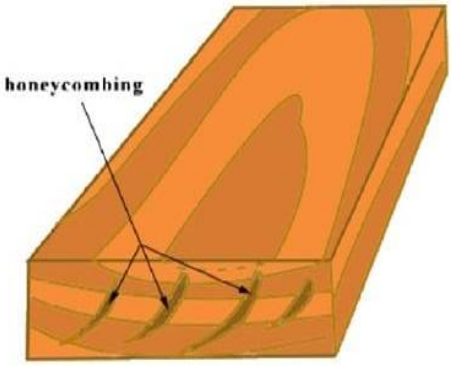


3.Twist

Twist is formed when the timber piece is spirally distorted along its length. It looks like propeller blade after twisting.

4.Honeycombing

Honey combing occur in the inner part of the timber which cannot be identified by just seeing. This is mainly due to stresses developed during drying of timber.

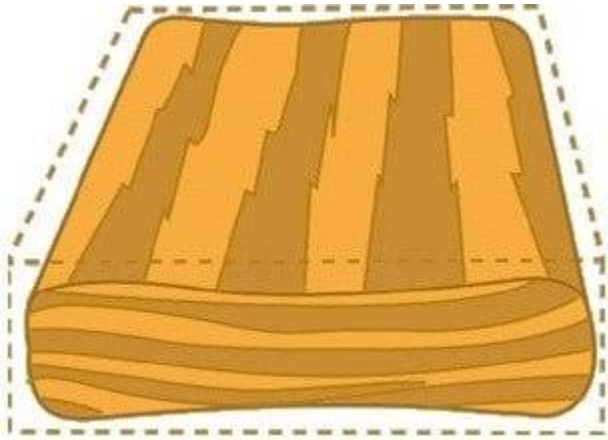


5.Case Hardening

Case is nothing but the top surface of wood which dries rapidly during seasoning but the inner part didn't. Then this defect is called as case hardening.

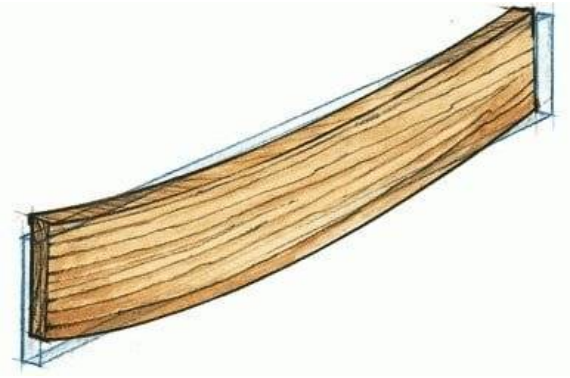
6.Collapse

During drying, some part of the wood may dry rapidly while some may not. Because of this improper drying shrinkage of wood occurs which results the defect called collapse.



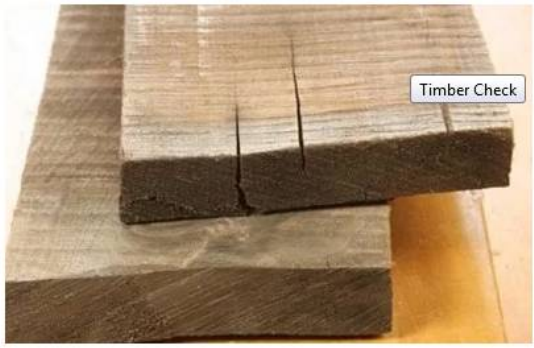
7.Warp

The loss of shape of wood due to stresses developed during drying is called warping. Cupping bowing, twisting of wood come under warping.



8.Check

Check is formation of crack in the wood which will separate the wood fibres. They are formed due to over seasoning of wood.



9. Split

Split is formed when a check extends from one end to the other end which will split the wood into number of pieces.

2.7 wood preservation

Preservation - Preservative treatment of timber forms a very important part of the national effort in conserving material resources and their most economic utilization. Before use in permanent structures, species of the following types of timber shall be chemically treated for protection against deterioration due to attack by fungi and termites, borers and marine organism, etc, in accordance with IS : 401-1982:

a) Heartwood of all species of timber of moderate and low durability;

b) Heartwood of all species of timber of high durability containing more than 15 percent sapwood; and

c) Sapwood of all species of timber of any class or durability.

Heartwood of all species of timber of high durability do not require preservative treatment except in cases coming under (b) above.

2.7.1 Need of wood preservation

wood preservation makes it possible to reserve precious durable species for export markets by replacing them on local markets with less durable but properly treated timbers. It is also a **necessary** condition for export trade in many **wood** products which are vulnerable to damage by fungi or insects.

The importance of wood preservation in tropical countries stems not only from the fact that large quantities of timber are involved but also because the rate of timber consumption in these countries is expected over the period 1961-75 to expand at a rate more than three times that in the rest of the world.

Climatic and biological conditions make wood preservation in the tropics even more important for four basic reasons:

1. In tropical countries particularly there are numerous species of wood-destroying insects and fungi.

2. Hot and humid weather in the tropics facilitates and speeds up any decomposition of wood.

3. Only a limited number of the great variety of tropical species is naturally durable

4. The lines of supply from the tropical forest to the final destination of the timber usually extend over comparatively long distances and the risk of damage by insects or fungi is a constant threat even after the finished product has arrived at its final destination.

These four factors make the preservative treatment of timber an indispensable condition for the proper development of wood utilization in tropical countries. Nevertheless the amount of timber which is given preservative treatment is rather limited in most of the tropical countries. In some cases, preservation facilities are almost nonexistent. In others, they are expanding too slowly to meet the real needs.

2.7.2 Natural durability of timber and wood destroying agencies

Durability. **Durability** is one of the key performance factors used to assess the suitability of a **timber** species for a specific application. The **durability** rating of a species is based on the natural ability of the heartwood of that species to resist decay and insect pests (including termites).

Natural durability

Natural durability refers to the natural resistance of wood against biologic degradation such as fungal decay and insect attacks (Cruz et al., 2015; EN 350, 2016). When transforming sapwood into heartwood over the tree's life, chemical and physical changes occur, depending on the wood species. As a result, the permeability of formed heartwood decreases, where as its natural durability increases due to the introduction of repellent and toxic products for fungi and insects. Nonetheless, it should be kept in mind that the natural durability and permeability of wood strongly vary according to wood species, geographic regions, and environmental exposure conditions of growing trees, individual trees, and different zones within individual trees (Viitanen et al., 2002). The long-term performances of timber structures as well as the viability of protection measures depend on the natural durability of wood and its treatability (i.e., permeability to preservatives). Meanwhile, natural wood resistance to biologic degradations can however be compromised if the MC of timber structures becomes higher than expected (above 20%–22%) during their service life (Cruz et al., 2015).

The natural durability of wood against decay fungi and insect attacks can be described with respect to four common European wood species .

A five-class system is used for the natural durability of heartwood to wood-destroying fungi:

(1) very durable;
(2) durable;
(3) moderately durable;
(4) slightly durable; and
(5) not durable.

Because it provides adequate conditions for fungal development (i.e., higher MC, sugar, proteins, cellulose), sapwood can be considered not durable (durability class 5) for all wood species, unless other data are available. Furthermore, the natural durability of sapwood against wood-boring beetles can be sorted out into two classes

D) Durable and
S) Susceptible.

It should be noted that house longhorn beetles (*Hylotrupes bajulus*) only attack softwoods. Although heartwood is stated durable in most of the cases, an extra class "SH" can be found for some wood species, standing for "susceptible of damage due to wood-boring beetles in heartwood."

Concerning the natural durability of heartwood to termites, a three class system can be used:

D) durable

M) moderately durable; and

S) susceptible.

Similar to fungal decay, sapwood is linked to the lowest durability class, "S," in case of termite infestation.

Biotic degradation

Under particular conditions, wood is subject to attack and degradation by a variety of organisms, including fungi, bacteria, insects and marine bores. These organisms attack wood in a variety of ways: some utilise it for food; some use it for shelter; and others for food and shelter. Fungi are among the most important wood-degrading organisms and require a suitable combination of moisture, temperature and air to grow. The optimum temperature conditions for fungi to grow in wood range from 22–30 °C. Wood is virtually safe from fungi and other biotic elements at temperatures below 0 °C and above 40 °C. Different species of fungi have slightly different moisture requirements but, in general, wood is at risk of decay when the moisture content exceeds around 20% for a prolonged period of time. Most decay fungi will become inactive and eventually die if the wood moisture content drops below this for extended periods. The natural durability of wood against fungal attack has been classified into five types according to the requirements for preservative treatment.

In tropical regions termites are the cause of a great deal of damage to timber structures, but in temperate regions damage by insects causes less economic loss than does fungal decay. The decay caused by fungi is different to that caused by insects. In order to control the biological decay of wood properly, it is crucial to understand the source of the damage.

Abiotic degradation

Climate has an important bearing on the durability of wood in terms of abiotic degradation. A number of environmental factors such as heat, oxygen, moisture (rain, humidity and snow), polluting elements and chemicals, and sunlight (ultraviolet) have the tendency to affect the service life of wood adversely, especially in outdoor applications. This degradation process, also called weathering, starts at the surface of the wood through photo-oxidation of the surface catalysed by heat and ultraviolet radiation in sunlight. It is augmented by other processes such as washing by rain, abrasion by wind-blown particles, changes in temperature and moisture, and reaction with the chemicals in air. Although the degradation process can take many forms depending upon the wood and the intensity of the exposure conditions, in general it begins with a colour change followed by slow erosion from the surface. The surface initially develops slight checking that leads to cracking. All of the four components of wood – cellulose, hemicelluloses, lignin and extractives – are affected by this form of degradation. For example, extractives undergo changes upon exposure to sunlight and lighten or darken in colour. Lignin, the polymeric substance cementing the cellulose together, is affected more by photodegration than is cellulose. The breakdown of lignin results in a loss of contact of the celluloses with the surface of wood. If the process continues, cellulose will be lost from the surface (a process called erosion).

The same timber pecies sometimes falling into different durability classes may be due to a combination of several different factors, including age, silvicultural system, specific timber

traits, weather and climatic conditions of the place of origin and where the wood is put into use. Thus, these factors can be broadly classified into endogenous and exogenous factors (Meyer, 2012).

Endogenous factors are those that originate from the wood itself,such as wood density, chemical composition and concentration of extractives, which collectively confer higher resistance.

Exogenous factors are those that are the result of the surrounding environment of where the wood is put to use, including the moisture regime of the location and the presence of decomposing organisms.

Endogenous factors

The endogenous factors responsible for durability are mainly attributed to the physical and chemical properties of the wood, such as density and chemical constituents. These secondary metabolites of low molecular weight, termed “extractives”, are present in wood (Chang et al., 2000) and are crucial for the natural durability of wood. Chemical extractives, such as alkaloids, phenols, resins, ter-penes, essential oils, quinones, silica etc., collectively appear to play a vital role in durability (Oshima, 1919;et al) They confer resistance against termites (Sen-sarma,et.al), fungi (Hawley et al.,) and marine borers. Several studies have clearly demonstrated that removal of extractives makes durable wood lose its natural resistance and render it more susceptible to deterioration and degradation (Ohmura et al., 2000;).

Other endogenous factors of wood, such as age and type of silvicultural practice (plantation-grown or naturally-grown), also contribute towards wood durability. Wood chemicals and physical characteristics, discussed above, can get altered depending upon tree age and silvicultural practices. Studies have suggested that timber from young or fast-grown plantation trees can have reduced colour and density; these trees also have lower natural durability than mature trees (Scheffer and Cowling, 1966; Bhat and Florence, 2003). For example, natural durability of T. grandis against termites was less effective in younger trees compared to mature trees (Rudman and Da Costa, 1959). Bhat and Florence (2003) examined T. grandis trees, ranging from 5 to 55 years, and found that juvenile wood from high input plantations was less decay resistant than the wood of 13-year-old trees and mature teak wood from forest plantations. Another study also found that extractive content varied among different age groups, and that plantation-grown teak showed lesser extractive content. Kokutse et al. (2010) pointed out that many factors, such as radial growth (which again depends on environmental conditions) affect heartwood formation in rapid plantation-grown teak. In the case of eucalypts, studies suggest that re-growth timbers have lower natural durability than timber from mature trees. This is because eucalypts produce juvenile heartwood for 8-12 years and may not produce fully mature heartwood until 35 years (Wilkes, 1984; Johnson et al., 1996). Studies by Anderson and Duncan (1963) and Rudman (1966) suggest that over- matured trees are also not good choices, as heartwood extractives degrade with age leading to a decrease in decay resistance in heartwood.

Exogenous factors

Climatic conditions where wood is put in use Harris (1961) commented that many timbers that were moved from their original growing area and introduced to new localities on the reputation of their durability failed to maintain this quality in the new area where they were exposed to different varieties of deteriorating organisms and conditions. Subsequent studies also have confirmed that the degree of deterioration of wood is dependent on conditions such as soil, rainfall, altitude, temperature and environ mental conditions under which the timber is put to use (Rao, 1982;et al). This is because climatic factors and their

seasonality greatly control and stimulate activities of the decomposer community, such as fungi and soil fauna, and thereby accelerate the process of decomposition .Many studies have related the seasonal variation in weather(atmospheric temperature, rainfall, soil temperature etc.) to the presence and efficiency of degrading community (both insect and fungi). In the case of insects (mainly termites), changes within a population show an annual fluctuation of composition in caste forms following a particular pattern (Esenther, 1969). Parameters such as atmospheric temperature and rainfall have been found to influence the seasonal foraging activities of termites (Haverty et al.1974,). A similar view holds true for microbial or fungal decay. Along with heat, oxygen and nutrients, suitable temperature range (0-40 C) and appropriate amount of moisture conten(20-200% as per FAO, 1986) are of prime importance (Dolby et al.1988;) as fungal spores require the surface of wood to be wet in order to germinate. In addition, fungi require that the moisture content of wood be above the fibre saturation point to establish a viable mycelial mat (Viitanen and Ritschkoff, 1991; Zabel and Morrell, 1992)

Bio-deteriorating agents

Along with climate, the type of bio-degrading agents also plays a major role in determining natural durability. For example, temperate and cold regions, termites are virtually absent, whereas they are very abundant in tropical regions (Brussaard et al., 2012). Hence, tropical and subtropical wood species have developed resistance against termites over time (Mohd Dahlan and Tam, 1985;Ling, 1996). In contrast, temperate woods lack those inherent resistance mechanisms against termites (Wong et al., 2005).

2.7.3 Type of wood preservatives, their characteristics ,composition and properties

Overview of Wood Preservative Chemicals

Wood preservative products are those that claim to control wood degradation problems due to fungal rot or decay, sap stain, molds, or wood-destroying insects. Both the treatment process and the use of treated-products can result in exposure to pesticides for both people and the environment. Most of the treatment processes and uses of treated products occur outdoors. There are wood preservatives that support a tolerance for indirect food-contact uses such as wooden crates, pallets, and stakes used to store or grow raw agriculture commodities.
Generally, freshly cut logs or lumber are treated and then manufactured into products such as:

- Seasoned building materials.
- Utility poles, fence posts and rails.
- Structural members.
- Structures and dwellings.
- Transportation vehicles (truck beds and support structures).
- Crop containers.
- Lawn furniture and decks.
- Playground equipment.
- Garden/landscape timbers.
- Log homes.

Chromated arsenicals (contains copper and some combination of chromium and/or arsenic):

Wood has been pressure treated with chromated arsenicals to protect wood from rotting due to insect and microbial agent attack and wood-boring marine invertebrates. From the 1970s to the early 2000s, the majority of the wood used in outdoor residential settings was chromated arsenical-treated wood.

Creosote

Creosote is obtained from high temperature distillation of coal tar. Pesticide products containing creosote as the active ingredient are used to protect wood against termites, fungi, mites and other pests that can degrade or threaten the integrity of wood products.

Currently, creosote is used for commercial purposes only; it has no registered residential uses. Creosote is a restricted use pesticide that can be used in outdoor settings such as in railroad ties and utility poles. Indoor applications of creosote are prohibited as well as application to wood intended for use in interiors or for use in contact with food, feed, or drinking water.

Pentachlorophenol (PCP)

PCP is a restricted use pesticide that is only used for commercial purposes such as utility poles, railroad ties and wharf pilings. Only pressure and thermal treatments of PCP are allowed.

Newer Wood Preservatives

Propiconazole

Propiconazole is a triazole fungicide that was first registered in 1981. Propiconazole has been used in millwork, shingles and shakes, siding, plywood, structural lumber and timbers and composites that are used in above ground applications only

Triadimefon

Triadimefon is a triazole fungicide that was used as a wood preservative . Triadimefon has been used for preserving wood-based composite products and wood products intended for above ground and in ground contact such as wood decking, patio furniture, millwork, guardrails, utility poles, foundation pilings, and fences. Triadimefon can be applied by dip or pressure treatment.

Acid Copper Chromate (ACC)

ACC is a wood preservative that is only used for industrial and commercial uses.

Newer Wood Preservatives for Residential Uses

These wood preservatives have lower toxicity profiles when compared to older wood preservativesThe following chemical wood preservatives are registered for treatment of lumber to be used in the residential lumber and timber market:

- Alkaline Copper Quaternary (ACQ.)
- Borates.
- Copper azole.
- Copper naphthenate.
- Copper-HDO (Bis-(Ncyclohexyldiazeniumdioxy-copper)).
- Polymeric betaine.

Of these chemicals, ACQ currently is the most widely used wood preservative for residential applications.

ACQ

ACQ (Alkaline Copper Quaternary) is a water-based wood preservative that prevents decay from fungi and insects (i.e., it is a fungicide and insecticide). It also has relatively low risks, based on its components of copper oxide and quaternary ammonium compounds. Water-based preservatives like ACQ leave a dry, paintable surface. ACQ is use on: lumber,

timbers, landscape ties, fence posts, building and utility poles, land, freshwater and marine pilings, sea walls, decking, wood shingles, and other wood structures.

Borates

Disodium octaborate tetrahydrate (DOT) is specially formulated for use as a water-based wood preservative and is used throughout Asia, North America and Europe. Typical applications include: furnishings and interior construction, such as framing, sheathing, sill plates, furring strips, trusses, and joists.

Copper Azole

Copper azole is a water-based wood preservative that prevents fungal decay and insect attack; it is a fungicide and insecticide. It is widely used throughout the United States and Canada.

Water-based preservatives like copper azole leave wood with a clean, paintable surface after they dry. Copper azole is used for treatment of millwork, shingles and shakes, siding, plywood, structural lumber, fence posts, building and utility poles, land and freshwater piling, composites, and other wood products that are used in above-ground, ground contact and fresh water as well as in salt water splash (marine) decking applications.

Copper Napthenate

Copper napthenate is used to brush, dip, spray, and pressure treat wood that will be used in ground contact, water contact, and above ground such as utility poles, docks, posts, piers, fences, and landscape timbers. Copper napthenate is effective in protecting wood against insect damage.

Copper- HDO (Bis-(Ncyclohexyldiazeniumdioxy- copper))

Copper – HDO is used to pressure-treat wood that will be used as decking, rails, spindles, framing, sill plates, gazebos, fencing, and posts. It is restricted from use in aquatic areas, construction of beehives, or any application associated with the packaging of food or feed.

Polymeric Betaine

Polymeric betaine is a borate ester that, when applied to wood, breaks down to DDAC (didecyl dimethyl ammonium chloride) and boric acid. Polymeric betaine is applied by pressure treatment to forest products.

2.7.4 PREPARING WOOD FOR PRESERVATION TREATMENT

Debarking: Some mills use water jets working at high pressure, the others use mechanical peeling.

Machining: All handling of wood by hand or machine should be carried out before preservation process. First of all, the wood to be treated is machined to the required dimentions and the surface is handled in such a way that the wood is ready for treatment.

Drying: Air-drying or kiln-drying is carried out for drying of wood.

Steaming: Steaming of timber in steaming vessels of plants enhance considerably the permeability of wood.

Incising: Incising is making small slits or incisions in the wood of difficultly impregnable tree species to provide the penetration of preservation solution along the grain in two directions.

Compression: Wood is passed through heavy rollers and the structure of compressed wood is changed to some extent that preservative liquid penetrates easily and uniformly.

Ponding and sprinkling: Ponding and sprinkling enhance the absorption of preservative with the dissolution and enlargement of the pits by bacterial activity.

2.7.5 PRESERVATION PROCESSES

Preservation Treatments for Unseasoned Wood:

Diffusion Processes

Osmose method: The method used widely is osmose method. Highly water soluble and concentrated product is applied to the debarked surface of freshly felled and wet wood, generally poles. Poles are covered with an impermeable covering for 1-3 months to allow the diffusion process go successfully. The formulation applied for pine, spruce and fir contains water, dinitrophenol, starch and adhesive.

Sap Displacement Processes

Boucherie method: The well-known sap displacement method is applied to the freshly-felled unbarked poles. The capsules put on the thicker end of the boles are connected with pipes to a tank containing 1.5% copper sulphate. The preservative flowing from the tank at a higher place to the capsules takes place the sap of the boles in a few days .

Non-pressure Processes:

Brushing and Spraying: Brushing and spraying are the simplest methods for applying preservative chemicals. Only surface penetration of 1-5 mm can be achieved.
Deluging: This is a treatment for sawn timber. Organic solvent preservatives is flooded over the wood surface while the timber is passing slowly through a short tunnel.

Immersion: Immersion is a treatment of dipping timber in a tank containing preservative for from 5-10 seconds to 1-2 weeks. The application gives better results with higher diffusion rates than brushing, spraying and deluging. Short periods of immersion are ideal for treatments of joinery components.

Hot and Cold Open Tank Treatment: The process is also known as Thermal Process. Hot preservative is pumped into the tank until the poles are completely immersed in the preservative solution for a period of six or longer hours. After the preservative is pumped from the treatment tank to storage tank the tank is flooded immediately with cold preservative solution. The cold solution brings about a partial vacuum in the wood cells and therefore more impregnation of the wood.

High-Pressure Treatments: These are the most successful methods in wood preservation. Wood is treated with chemicals under high pressure in steel pressure Wessel.

The Full-cell Process (Bethell Process): The aim of the process is retaining maximum amount of preservative in the wood. Water-borne and also oil-borne chemicals are always applied by full-cell process. Creosote is only employed by this treatment when some special structural elements such as marine piling are treated with high retention rates of the preservative. There are five stages in Bethell process:
a) Initial vacuum (635 mm Hg) for 15-60 minutes.
b) Filling the vessel with preservative solution.
c) Pressure (10-14 kp/cm2) for 1-6 hours.
d) Draining preservative after releasing the pressure.

The Empty-cell (Rueping) Processes: The methods were generally invented to reduce the amount of creosote used in the treatments with the same penetration. In the treatments with the same penetration. In this procedure there is no initial vacuum and a large amount of the creosote is expelled from the wood by the compressed air trapped within, leaving the cell walls thoroughly treated.

There are five stages in the process:
a) Initial air pressure (4 kp/cm2).
b) Filling the vessel with preservative.
c) Pressure (10-14 kp/cm2) period for 1-3 hours.
d) Draining preservative after releasing the pressure.
e) Final vacuum (600 mm Hg, 10 minutes).

Lowry process: This method differs from the Rüeping process in hat preservative is pumped into the vessel against atmospheric pressure. No initial vacuum or pressure is applied and less solution is forced out of the wood than with the Rüeping treatment.

Oscillating Pressure Method (OPM): The difficulties encountered using the Bethell process for treatment of very resistant wood species lead to the use of repeated cycles of vacuum and pressure with the improvement of penetration. The high pressure is 8 kp/cm2 and the vacuum 720 mm Hg. Green or seasoned timber is treated with water-borne chemicals, generally CCA formulations. The method is specially applied to the poles of resistant species such as spruce and fir.

Alternating Pressure Method (APM): In this modified method the alternating pressure changes within each cycle from 8 kp/cm2 to atmospheric pressure. Also green and difficultly impregnated wood can be treated by the process, eliminating drying of the timber.

Ultra-high Pressure Method (HP): A full-cell process using a pressure of about 70 kp/cm2 is introduced with the aim of improving the penetration and retention of preservative in eucalpt species which is difficult to impregnate by other methods.

Low-Pressure Treatments:

Double Vacuum Process: The treatment has remarkable industrial success in the United Kingdom with hundreds of plants in operation. Since the timber can be glued, painted or glazed in a few days after the treatment, the process is well suited to the needs of joinery industry. There are five stages of treatment.
a) Initial vacuum of 250 mm Hg (3 minutes) for pine and 625 mm Hg (10 minutes) for spruce.
b) Filling the vessel (rectangular or circular cross-section) with usually an organic solvent type preservative solution.
c) Pressure of about to 2 kp/cm2, 3 minutes for pine and one hour for spruce.
d) Drainig the preservative after the pressure is released.
e) Final vacuum of 500 mm Hg for 20 minutes.

In situ Remedial Methods Bandage Method: Ready-made bandages containing Pol-Nu Type and Wolmanit-TS are placed on the transmission poles at the ground line to control decaying and extend service life.

Cobra Process: The process was developed as a remedial treatment also for transmission poles at the ground line. Generally a Wolman type salt (Fluor-chrome – arsenate – phenol, a mixture sodium fluoride and chromate and 2,4-dinitrophenol)is forced through a needle into the pole.

Drilled Hole Method: The method is applied to wood structures with a high risk of decay such as bridges and piles in water. The holes drilled at a diameter of 15-25 mm is filled with solid preservative and closed to allow the chemical impregnate the wood by diffusion.

2.7.6 Factors affecting penetration of preservatives

Permeability and chemical distribution are important properties in wood applications and depend on the manner of penetration and fluid flow into the wood (Yudodibroto and Walters 1977). These properties play a major role in the wood preservation and paper making or pulp preparation processes (Siau 1984). One of the properties that has great impact on the wood treatability in addition to the absorption rate, is fluid distribution in the wood (also called micro-distribution) (Drysdale et al. 1980,). The factors such as tannin and nutrient presence can influence on the chemical distribution (Hulme and Butcher 1977). Therefore, conventional indices such as absorption rate are inadequate to obtain the required properties in wood impregnation. To insure proper treatment, the amount of absorbed chemical and its distribution in the wood should be investigated (Stefan et al. 2002). Several factors affect the permeability and absorption of impregnation solution. Some of these factors are included: wood structure, moisture content (MC), impregnation method, features of impregnation solution, wood preparation method, etc. (Nicholas and Siau 1973). MC is one of the important factors that affects the chemical penetration into the wood. The permeability of hardwoods decreases with increasing wood MC due to increasing the vessel volumes.

Factors Affecting Penetration and Absorption

The amount of preservative necessary for adequate protection is mainly governed by the end use of the timber. For instance, timber to be used in ground contact would need a higher absorption of the preservative than for a roof timber. However, absorption in itself is not a complete measure of the treatment, as it is important to have a complete and uniform penetration to a depth as deep as possible. Inadequately penetrated wood may be subjected to an early failure as a result of an extension of a check or a split beyond the treated zone. The main factors affecting penetration and absorption are:

(a) the anatomy of wood
(b) the treating procedure
(c) the preparation of material

2.7.7 PROPERTIES OF TREATED WOOD

Strength: Waterborne preservative treatments generally reduce the mechanical properties of wood. The treatment does not reduce the load carrying capacity to below acceptable levels. Incising may cause a slight decrease in strength but it gives an increased protection. Unless the steaming treatment period kept as short as possible, serious weakening of the wood can be observed. High pressure can brings about collapse of wood cells, especially with woods of low density. When the wood is treated to accepted chemical loading by normal industrial preservation methods any significant losses of strength is observed.

Flammability: Wood processed with water-borne salts has no greater flammability. However the wood treated freshly with creosote or heavy oil mixtures presents greater fire hazard. Therefore, mine props are processed with water-borne salts. After a few month creosote treated wood presents no fire hazard.

Electrical Conductivity: Creosote and organic solvent preservatives have no effect on the conductivity. Although water-borne chemicals change the electrical conductivity slightly, the differences are small and can be ignored for practical purposes.

2.7.8 TESTING OF WOOD PRESERVATIVES AND TREATED TIMBER

Testing of wood preservatives

Wood is one of the most valuable and versatile resources for all sorts of constructional purposes. But timber in its various forms is subjected to several types of deterioration. This standard lays down the method for the laboratory determination of threshold value of wood preservatives against fungi. Most chemicals are initially tested for their ability to control decay fungi in agar-block tests. In an agar-block test, blocks of wood containing a predetermined retention level of chemical are exposed to wood-destroying species of both brown-rot and white-rot fungi. The blocks along with the fungi inoculums are placed within a sealed dish containing agar. Efficacy is measured as a loss of block weight. The test fungus to a medium containing known concentrations of the test chemical, or soaking filter paper in the test chemical and placing this on the surface of a previously inoculated plate. The presence of the fungus and its growth rate are used as a measure of chemical effectiveness. These results are then compared with results of similar tests on accepted preservatives. Whereas this method provides a relative measure of toxicity, the growth of fungi on artificial media is markedly different from growth in wood. This test method varies widely between laboratories. The efficacy of wood preservatives provide valid data, the time required to obtain definitive results is too long because reliable decisions on efficacy against wood decay organisms must rely on long-term field test data. This goal will not be realized until we develop a better understanding of the many variables that influence microbial decay rates, develop improved methods for detecting and quantifying the extent of wood decay and couple these developments with improved designs for test specimens and methods. The main objection to the malt-agar toxicity test is that the substrate is not wood. But this testing method takes minimum time among other methods which is save the time, money and labor of the users.

Requirements of a Good Preservative

In order to be generally useful, a wood preservative mus t
(a) be toxic to the organisms that injure or destroy wood,
(b) havesuitable permanence,
(c) have satisfactory penetrating properties,
(d) be safe to handle and use,
(e) be harmless to wood and metal, and
(f) be inexpensive and plentiful .

For the treatment of certain special products, such as millwork or manufactured articles, it may also be required that the preservative be paintable, odourless, colourless, fire resistant, moisture repelling, or no swelling, or that it have combinations of several of these or other properties . The relative importance of the different requirements depends upon the character of the product treated, the purpose for which it is to be used, and the conditions of service.
Toxicity is required in all wood preservatives, in order to make the wood poisonous to the various organisms that damage it. It seems possible for preservatives to be repellent toward some insects without being toxic, but for general effectiveness, and especially for protection against fungi and marine borers, toxicity is necessary. It is not infrequently claimed that decay prevention is accomplished by "waterproofing" the wood, but this is incorrect for no waterproofing" material or treatment yet discovered, that is practical for common use,
does more than retard the rate of water absorption .Under continued exposure to dampness, the wood can usually absorb enough water in a few weeks or months, even through the best

of "waterproofing" treatment, to permit its decay.- This is one of the reasons why paint does not prevent decay. Since treated wood must last many years in order to give satisfactory service, it is apparent that a preservative must have a considerable degree of permanence. No preservative is acceptable that evaporate steadily or that otherwise disappears in a short time from the wood or changes chemically into compounds that are ineffective. Benzol and turpentine are examples of chemicals that are toxic but that evaporate from the wood too quickly to give the desired protection. Complete resistance to evaporation, leaching, or chemical change is not required, but the rate at which the preservative becomes ineffective met be so slow that adequate protection is afforded over a sufficient period of time .

preservative should not be dangerous to handle nor make the treated wood hazardous to the health of the men who must prepare it or build with it . It must not endanger persons or animals

Any preservative, if taken internally in sufficient quantity would probably cause death, but that is true of most of the chemicals in daily domestic or industrial use and is not a valid objection . Any special hazard, however, such as explosiveness, high fire danger, extreme poisoning hazard, or tendency to produce occupational disease, may prevent the commercial use of an otherwise suitable material .Preservatives must penetrate wood satisfactorily in order to be acceptable . It is not reasonable to expect deep penetration by mere brushing, or brief immersion, although that would be highly desirable , if obtainable, Good penetration by such methods is not infrequently claimed for new preservatives, but, so far as is known, it has not been successfully attained . New preservatives, however, should penetrate as satisfactorily as those in common use, when applied by pressure or by other suitable methods.

The protective zone must be deep enough so that it is not easily broken through in handling or by the ordinary wear and season checking to which wood is normally exposed in service .

Preservatives that attack wood and seriously reduce its strength are obviously unsuitable for prolonging its life . Corrosiveness to metal is also undesirable for corrosive preservatives damage the treating apparatus as well as the bolts, nails, and other metal with which the treated wood must be in contact when in use .

Low cost and a plentiful supply are important requirements in a new preservative unless it is so outstanding in other respects that its cost becomes of secondary importance. The value of the product being treated, the service life desired, and competition with other materials largely determine the permissible cost . The commonly used preservatives are low in price, when purchased in large quantities, and are not likely to be supplanted by new materials that markedly increase the cost of treatment. Retail prices are necessarily much higher because of the greater cost of packaging, selling, and distributing .Colour, odour, and painting properties are usually not important considerations in the treatment of railway ties, piling, fence posts, and many other forms of timber that are to be used out of doors or in contact with the ground. In highway guard posts, however, and sometimes in fences around houses and estates, or in telephone or power line poles, cleanness and paintability are important items . In residences and other buildings, it is usually desirable that the preservative leave the wood just as free as possible from colour and odour and as suitable as untreated wood for all types of stains, paints, varnishes, and other finishes.

It is seldom demanded that a preservative make the wood highly resistant to fire, although this would often be of great advantage .It is a definite disadvantage, however, if the preservative increases the flammability of wood used in buildings or other structures where fire hazard is of importance. Preservative that would prevent moisture changes in wood in service, and thus prevent shrinking and swelling, would be advantageous in many uses of wood . Since it is a requirement that cannot be met by the preservatives now in use, it is not

demanded in new preservatives for general use. If such a preservative ever is developed it will undoubtedly find fields of usefulness not now met by any preservative. special requirement in the treatment of manufactured articles, such as furniture, millwork, store and office fixtures, and similar products, is that the preservative, when injected, shall not swell the wood, for swelling causes grain raising, distortion of plane surfaces, and severe stresses in the joints . The shrinkage that takes place during the seasoning of wood swelled in treatment leaves open joints and warped, roughened surfaces . For these reasons, water-borne preservatives are seldom used in the treatment of furniture and millwork and toxicants carried in organic, nonswelling solvents are preferred.

Laboratory Tests

Much useful information can be obtained through laboratory testing methods on toxicity, penetrating properties, corrosiveness to wood and metal, painting properties, color, odor, fire resistance, fire and explosion hazard, water repellence, and swelling . Laboratory tests also give information on various factors that affect permanence, such as volatility, leachability, and chemical stability, but not enough to obviate the necessity of service tests on materials of promising character .Health hazards to workmen handling the preservative and the treated material, and to others who may subsequently have contact with the treated wood or be influenced by it are difficult to determine accurately .

Toxicity.

The malt-agar culture method and the wood-block method are the two general methods of making tests for the toxicity of chemicals to fungi. Both give useful, comparative information, but both are purely empirical. The results by either method are influenced very greatly by the details of manipulation as well as by the species of fungus used as the test organism . Results obtained by the two methods are not directly comparable, and often different workers using the same method differ enough in their technique to cause considerable variations in results .The malt-agar culture method, which is the toxicity method most commonly used in the United States for wood preservatives, consists in growing the test fungus on malt-agar culture media containing different concentrations of the preservative with non-volatile materials, petridishes may be used as containers, but, when it is desired to reduce moisture losses during the test, or to prevent evaporation and loss of volatile materials, closed Erlenmeyer flasks may be employed .After the culture media containing the different concentrations of preservative have been prepared and poured into the petridishes or flasks , a small square of healthy mycelium cut from a specially grown culture is planted in each container . At sufficiently low concentrations, the fungus will grow and spread out over the culture medium while at higher concentrations the fungus transplant may be killed by the preservative. An intermediate concentration may be found at which the fungus will not grow, but at which it is not killed. This is called the total inhibition point. The lowest concentration at which the fungus is killed is called the killing point. These two values are expressed as percentages of the concentration of the preservative in the culture medium. In working with a new preservative, it is often desirable to use rather wide variations in concentration in a preliminary test to locate the killing point approximately, and then to determine it more accurately by a retest, using smaller variations in concentration in the vicinity of the approximate killing point . Since each set of determinations requires a month or more, a complete series of tests may have to extend over 3 to 6 months, or even longer.

The killing point values obtained vary considerably with different species of fungi (2) . For a preliminary survey, it is often sufficient to use one fungus, but in any comprehensive study, several species should be employed. When using only one fungus in the agar plate toxicity test, the Forest Products Laboratory usually employs a special strain of a fungus

known as Madison No . 517, which grows well in the laboratory and has been found very suitable for the purpose .In Europe, investigators prefer to make toxicity tests by treating wood blocks with different concentrations or absorptions of the preservative under test and then placing *them* in flasks on mats of vigorously growing fungus. Untreated wood is placed in each flask with the treated wood, for comparative purposes. As in the agar-plate method, it is desirable to use several species of fungi . The exposure is usually continued for 3 or 4 months, after which the blocks are removed, examined for softness, then dried and weighed. The amount of deterioration of the wood, as indicated by loss in weight and strength, and concentration of preservative required to prevent the growth of the fungus, afford base for comparing toxicities .The European method gives excellent results and is widely used.

Other wood block methods are also used to some extent which follow the same general principles as the European method, but vary in details the fact that the test is made in wood, the material the preservative is intended to protect, is an advantage. A disadvantage is that the block test requires 2 or 3 times as long as that using the malt-agar culture medium .Wood preservatives is sometimes tested for toxicity against bacteria. The results obtained are practically valueless as an indication of wood preserving effectiveness because the test organisms are not wood destroyers and their behaviour is not indicative of the behaviour of wood destroyers .The results of toxicity tests must be used with caution . Differences in toxicity are too frequently assumed to be a direct measure of the relative effectiveness of preservatives, or to indicate the quantity required per cubic foot of wood to afford protection, neither of which is correct. Other properties, especially permanence, are of equal or greater importance. The most toxic preservative is valueless without sufficient permanence and comparatively low toxicity may be acceptable if permanence, cost, and other properties are favourable. Very high toxicity, when other properties are also favourable, indicates the possibility that low concentrations of the toxicant in the preservative solution, or low net absorptions of the preserving compound, may be sufficient. It is not safe to risk the protection of important structures or products upon this assumption, however, until its correctness has been demonstrated by field experiments and service records.

Penetration.

Accurate comparisons of the penetrating properties of different preservatives are difficult to make because of the great variability of wood in resistance to penetration . Even in different parts of one face of a piece of wood, the penetration frequently varies by several hundred percent . There are also wide differences in penetration in different directions of the grain .

End or longitudinal penetration, for example, usually averages more than 5 times the side penetration and sometimes is as much as 50 times as great. End penetrations of 15 to 2 0 times the side penetration are common . There is also a difference between side penetration across the annual rings (radial penetration) and side penetration parallel to the annual rings (tangential penetration), the tangential penetration being greater, in most species, Penetration usually is very much greater in sapwood than in heartwood although there are exceptions to the rule .For the foregoing reasons, specimens selected for comparative penetration tests should be either all sapwood or all heartwood, long enough to avoid complete penetration from the ends, and of large enough cross section to allow' separate measurement of radial and tangential penetration. They should also be closely matched so as to be as nearly alike as possible in density, rate of growth, direction of grain, and other characteristics that may influence penetration. When practicable, it is desirable to make the specimens square in cross section, with two sides showing edge grain and two sides showing flat grain . Many experimenters and promoters of new preservatives have deceived themselves and others by failing to observe the above precautions. Salesmen also, by selection of easily penetrable

wood and dependence upon end penetration alone, sometimes induce prospective customers to believe that their product has remarkable penetrating properties .While accurate quantitative comparisons of penetrating properties are not practicable, it is possible, with materials that are coloured or can be made to give colour reactions, to make rough comparisons and to learn whether the new material is significantly different in this respect from those in common use . The depth of penetration of creosote and other coloured oils is easily distinguishable upon cutting into or splitting open the treated wood. Copper sulphate and certain other salts also have sufficient colour to be seen. Zinc chloride and sodium fluoride are examples of preservatives that are colourless, but whose presence can bemade visible by spraying the treated surfaces with chemicals that produce coloured compounds when they react with the preservative, or that are coloured themselves, but are changed in colour by reaction with the preservative in the treated parts of the wood . With colourless preservatives for which no colour tests have been devised, it is difficult and often practically impossible to obtain even a good approximation of the depth to which they have penetrated . The addition of dyes to colourless solutions does not give accurate indications of penetration because the dye frequently filter out or fail to penetrate as far as the preservative .

A rough indication of the probability of good penetration can be obtained, for materials that do not react with the wood, by a consideration of their viscosities for; other things being equal, lower viscosities favour deeper penetration. When testing the penetrating properties of a proprietary preservative, consideration should be given to the claims made by its promoters and the tests made accordingly. For example, preservatives recommended for application by brush or other superficial method should be applied in that way in the test, whereas preservatives recommended only for pressure treatment should be applied by pressure.

Volatility.

The volatility or loss of preservative by evaporation from the wood in service is governed largely by the vapour pressure of the preservative at the temperatures to which wood in service is exposed. Data on the vapor pressures of many chemicals are not so complete as may be desired, but the boiling point of most chemicals is known and constitutes
a fairly good index of their volatility at ordinary atmospheric temperatures . The volatility of oils and mixtures of oils can be studied by making fractional distillation tests by the standard distillation procedure in use for coal-tar creosote, and comparing the results with those obtained, from creosote . With organic solids, determinations of melting point and boiling point are useful, as well as behavior on continued heating at different temperatures. Inorganic solids seldom are volatile .

Leachability.

Then treated wood is in contact with water, the preservative may be gradually dissolved out of the wood by the water.

No chemicals are absolutely insoluble in water, but some have such low solubility that they leach *very* slowly. The toxic constituents of coal-tar *creosote*, for example, have such low solubility in water and leach so very slowly that the creosote gives protection to structural timbers for periods as long as 50 years or more, if present in substantial quantity to begin with. Although creosoted wood usually does not last that long, its ultimate destruction is ordinarily caused by factors other than leaching. Even preservatives that are readily soluble in water, if originally injected in suitable quantities, require some years to leach to the point where they no longer afford protection. When preservatives are sufficiently soluble to make water solutions of satisfactory strength for treatment, differences in their solubility are not a measure or resistance to leaching. For example, zinc chloride is soluble in water in practically all proportions while the solubility of sodium fluoride is only about 4 percent at normal atmospheric temperatures, yet the rate at which they leach from wood is very similar. There

is no standard method of making leaching tests, but a common method is to impregnate blocks of wood, submerge them in water for definite and repeated periods of time and make analyses of the water to determine the amount of leached chemical it contains. Analyses may also be made of the wood after leaching. With some chemicals, such analyses can be made rather simply and accurately.

Other chemicals require much more inconvenience, time, and expense ; for some, satisfactory methods of analyses may not even be available . On the whole, comprehensive and reliable leaching tests are both expensive and time consuming .The chemical stability of a preservative in wood is one of the most difficult properties to measure in the laboratory. It is sometimes possible to classify a material as unpromising because of its known tendency or the tendency of chemically related materials to decompose spontaneously or to react with water, oxygen, or carbon dioxide. The fact that a material reacts vigorously with some constituent of wood - at a high temperature leads one to suspect that a slow reaction may take place at ordinary temperatures, even though such reaction is not at once apparent .There are no standard tests for chemical stability and when a special study of this property is required the methods of investigating it must be selected according to the nature of the chemical under consideration.

Accelerated field tests can be made by treating stakes or saplings of small cross section and placing them in the ground in a soil and climate that favour rapid deterioration. The rate of deterioration is noted by pulling the stakes and inspecting them once or twice a year. Untreated stakes should always be included for comparison. Although the test specimens are exposed to natural conditions, their small cross section and their large ratio of surface area to unit volume favour more rapid loss of preservative by leaching, volatility, and some types of chemical change than takes place in timbers of structural size. The balance between the factors that govern the loss of preservative is not the same in small specimens as in larger pieces .The specimens should preferably be all sapwood and complete penetration of preservative should be obtained so that no failure will result from incomplete penetration. A range of absorptions should be used with each preservative tested, including some that are above and some below the absorptions recommended for ordinary commercial use . The conditions to which the field test specimens are exposed are more representative of severe service conditions than any laboratory test .The irregular periods of wetting, drying, freezing, thawing, and exposure to sunlight occurring in actual service, as well as the variety of chemicals, fungi, and insects present in the soil, create such complicated and varying conditions of exposure that it is not practical to simulate them in laboratory tests. Since these conditions are also constantly varying in a field test and are different in different localities, direct comparisons between preservatives can be made only when their respective test specimens are exposed at the sane tine and place, While a field test of this character may properly be considered an accelerated test, it cannot be completed quickly for good preservatives may protect even these snail specimens for 10 years or more. It is also impossible to predict with accuracy from an accelerated field test how long treated structural timbers will last in service. The field test , however, next to service tests of full-sized timbers of various classes , affords the best method of comparing different preservatives and, if it is conducted carefully and on a sufficiently comprehensive scale,

Wood is resistant to attack by most chemicals and is seldom damaged by preservatives. Strong acids and alkalis destroy it in time and certain other chemicals, in concentrated solution attack it. The probability of attach by a new preservative can usually be determined from its chemical composition. When tests are necessary, they may be very time consuming and expensive and may have to include comparative strength tests on treated and untreated specimens. No standard method of testing this property has been devised

.Comparative corrosiveness to metal can be measured by hanging strips of metal in containers of the respective preservative solutions maintained at constant temperature, and noting their loss in weight from time to time, Another method is to drive nails or screws, made of the respective metals, into treated wood, expose the wood to different moisture and temperature conditions, and then measure the amount of deterioration cf the metal by, noting the loss in weight, the depth of corrosion, er the loss in strength . While there is no standard test for the purpose, it is usually possible to obtain sufficient information by the above methods to determine whether the preservative is noticeably harmful to wood or metal.

Painting properties, or the effect of a preservative on paint films applied over it, may be apparent in at least three different ways, namely, bleeding of preservative through the film, staining of the film by dissolving some of the preservative, and reduction of the normal life of the film. Coal-tar creosotes and similar oils are not satisfactorily paintable because of bleeding and staining, and they probably also reduce the serviceable life of the paint. Zinc chloride and other water-borne, inorganic preservatives, as a rule do not stain or bleed through paint, but some of them may decrease its life, Any preservative that discolours wood will, of course, reduce its suitability for transparent finishes .Tests on the staining of paint can be made by applying paint to treated wood, in sawed and round forms, and observing the extent to which discoloration occurs. The same specimens can then be placed outdoors where they will be freely exposed to sunshine. Observations for bleeding and staining should be continued through at least 1 year. By continuing the exposure over 4 or 5 years, information can also be obtained on the life of the paint coating. For a conclusive test on the effect of the preservative on paint durability, however, it is necessary to include both treated and untreated specimens of otherwise similar character and in sufficient numbers to give averages that are reliable and are not too greatly influenced by the behaviour of single specimens, Several types of paint should be used and the test should be continued long enough to require one or more repainting. Observations made within a few months after painting are not conclusive on the question of durability, and may be very misleading. The technique of testing paint durability is not simple and a careful study of paint testing methods is desirable before important tests on the paintability of preservatives are started .

FireRetardance .

The extent to which a preservative changes the resistance of wood to the spread of fire can be measured by the "fire - tube" test. This test indicates any marked change from the performance of normal untreated wood . However, it does not indicate directly the ease of ignition of the treated wood or its resistance to charring through or "penetration," upon continued exposure to flame or high temperatures .No satisfactory test is known for ease of ignition . Resistance to fire penetration can be compared by placing test specimens over a standard flame or over the opening of a furnace maintained at a definite temperature or temperature range, and observing the time required for the temperature of the outer face to rise a given number of degrees above its original temperature, or for flame to show through. These small scale tests give very useful indications as to how the treated wood compares with the untreated and they usually are sufficient. When the necessary apparatus is available, the tests need not be very expensive unless conducted on an elaborate scale . If more conclusive evidence is required, it may be necessary to build complete structural units of treated and untreated wood and expose them to large scale, standard fire tests, which are very expensive .

Water Repellence.

This property is confined to materials of oily, waxy, or resinous nature for inorganic salts are not water repelling .The capacity of a preservative to reduce the rate or amount of water absorption in wood can be studied by exposing treated and untreated specimens to high humidity or to water for different lengths of time and noting their respective changes in

weight and dimensions. The amount of change in the treated pieces during a given period of time, compared with that in the untreated pieces, affords a measure of the effectiveness of treatment. The length of the exposure period, however, influences the results enormously. In very short exposure periods, the untreated wood may absorb considerable water while the treated specimens absorb practically none. Over a period of two or three weeks, however, it may be found that the treated wood has absorbed about as much water as the untreated. Almost, if not all, treatments merely retard the rate at which water is absorbed, but do not prevent it . Untreated wood, when submerged in water, absorbs water quickly at first and then more slowly until it reaches the saturation point, after which no more water can be absorbed. The treated wood absorbs water more slowly from the beginning but, if allowed to remain in the test long enough, it ultimately absorbs just about as much as the untreated , if allowance is made for the space taken up by the preservative . The behaviour is very similar when the specimens are exposed to air at high humidity, instead of to water, the principal difference being that the maximum amount that can be absorbed by the specimens is the amount required to bring the moisture content of the wood up to the equilibrium point corresponding to the air humidity. Comparative values of water - repelling effectiveness, therefore, are practically meaningless unless the time of exposure is stated.

The fire and explosion hazard of the preservative during its preparation and storage, and during the treatment and the subsequent handling of the freshly treated wood can usually be determined sufficiently from the composition of the preservative. Water solutions of inorganic salts, of course, usually present no fire or explosion hazards. Oils and the common organic solvents have fire and explosion hazards more or less in proportion to their volatility. There are some solvents, of course, particularly those containing a high proportion of chlorine, that are volatile, but do not burn readily, if at all . The health hazard of a new material cannot be determined quickly or easily. Usually the character of the material will give some information as to the probable health hazards connected with its preparation, handling, and use, for long experience in the industrial use of chemicals of various kinds has furnished much information of this character . When experimental work is required on a new material to learn to what extent it is dangerous to health, the experiments should be made by specialists in this field.

Other Properties.

Some properties, such as colour and odour, usually do not require formal tests for they can be readily observed . The tendency- of the preservative solution to swell wood can usually be deduced from the composition of the solution, but can easily be tested by noting whether swelling takes place when wood is treated. Tests for other special properties, if required, must be devised according to the specific requirements to be met and the general character of the material under test, Precautions should be taken in all tests conducted, to see that the test specimens and their method of preparation are such that they give representative results. Abnormal absorptions, for example, should be avoided unless the character of the test makes them necessary. Preservatives promoted for superficial application only should not, ordinarily, be applied to the test specimens by more thorough methods. The size and shape of the test specimens should receive careful consideration so that excessive end penetration does not lead to false conclusions. Absorptions used in durability and permanence tests should be chosen with consideration for the absorptions used or recommended for commercial practice. The number of test specimens should be sufficient to give dependable averages and, in all other ways, every care should be taken to avoid reliance upon no representative material or inadequate tests.

TESTING OF TREATED TIMBER

Penetration and Retention Sampling Requirements

Samples should be taken in clear, straight-grained wood away from knots, splits, checks or other defects and at a minimum distance from the end or edge of pieces as indicated in the table below. Samples shall be representative of the charge, but where mixed charges occur, sampling shall be directed at the produce considered to be the most difficult to treat.

Hazard Class	Preservative Type	Minimum distance from piece end (mm)
H1 Group A	Boron compounds CCA	300 450
H1 Group B	Boron compounds CCA	150 from one edge
H3 Group A H3 Group B	CCA, LOSP CCA, LOSP	450 150 from one edge
H4 Group A H4 Group B	CCA CCA	600 150 from one edge
H5 Groups A, B and C H5 Group D	CCA CCA	600: sawn timber Poles: ground-line 150 from one edge
H6	CCA	Mid-point

LOSP- contains such chemicals as Tri-butyl tin oxide,copper naphthenate or Pentachlorophenol
CCP- Chromated Copper Arsenate

Penetration and Retention Tolerance

For most Hazard Classes the penetration and retention requirements must be met in a minimum of 90% of the samples in any set. Exceptions are in the heartwood penetration requirements in Hazard Class H4 where the requirement must be met in a minimum of 60% of the samples in any set.

Substandard Treatments

Timber charges represented by samples not meeting the requirements of this specification shall be classed as substandard and shall either be redried and retreated, rebranded in a lower Hazard Class whose requirements it meets, or its brands removed and the timber sold as untreated.

Chemical Tests for Presence of Preservative

Boron

Pyrocatechol Violet Test “PCV Test” – Reagents
Reagents (1) 0.2% solution of pyrocatechol violet in water (2) Buffer solution pH 9-8.2
Pyrocatechol Violet “PCV” Solution
Make a solution of 2g per litre of the dyestuff in distilled water. Add a few mls of chloroform to stop mould growth. Store in a brown glass bottle out of direct sunlight and out of contact with any metals : under these conditions storage life is virtually indefinite

Phosphate Buffer for “PCV” Solution

0.68g of anhydrous potassium dihydrogen phosphate A.R. previously dried at 110°C and 13.49g of disodium hydrogen phosphate A.R. dried at 130°C and dissolved in 1 litre of distilled water.

Alternatively, make a 2% solution of sodium dihydrogen phosphate A.R. and using a pH meter, add 20% sodium hydroxide solution until the pH of the solution is between 8.0 and 8.2.

A brown glass bottle is preferable for the storage of this buffer solution as there is a tendency for algae to grow in it.

Spray the freshly cut sample with solution (1), allow to soak in then spray with solution (2)

Samples containing sufficient boric acid to comply with TPC requirements will show a distinct pinkish-red colour, borderline cases at about 0.2% boric acid will show a muddy brownish green colour and inadequately treated areas will appear yellow. Very heavily loaded areas may appear whitish. Care should be exercised in spraying the reagents, particularly on denser timbers, as the spray may run and give an incorrect interpretation of the result.

Copper (as present in CCA and ACQ treated wood)

Rubeanic Acid Test

Reagents: (1) 5% ammonia solution (2) 0.5% rubeanic acid (dithio oxamide) in alcohol

Ammonia Buffer for Rubeanic Acid Test

Dilute 1 part of 0.880SG ammonia with 6 parts of distilled water or 1 part of 0.91 solution with four parts of distilled water.

Rubeanic Acid (Dithio oxamide) Solution.

5g of rubeanic acid dissolved in a litre of a mixture of 90 parts ethanol and 10 parts acetone. Iso-propyl alcohol may be substituted for ethanol if required.

Spray specimen with (1) followed by (2). Copper-containing areas show a greenish black to almost black colouration, untreated areas retain natural wood colour. The colouration is substantially permanent and samples may be kept for reference for a period of years if needed.

2.7.9 Treatment of timber for difference uses

Strength: Waterborne preservative treatments generally reduce the mechanical properties of wood. The treatment does not reduce the load carrying capacity to below acceptable levels. Incising may cause a slight decrease in strength but it gives an increased protection. Unless the steaming treatment period kept as short as possible, serious weakening of the wood can be observed. High pressure can brings about collapse of wood cells, especially with woods of low density. When the wood is treated to accepted chemical loading by normal industrial preservation methods any significant losses of strength is observed.

Flammability: Wood processed with water-borne salts has no greater flammability. However the wood treated freshly with creosote or heavy oil mixtures presents greater fire hazard. Therefore, mine props are processed with water-borne salts. After a few month creosote treated wood presents no fire hazard.

Electrical Conductivity: Creosote and organic solvent preservatives have no effect on the conductivity. Although water-borne chemicals change the electrical conductivity slightly, the differences are small and can be ignored for practical purposes.

Safety

Domestic and Industrial Buildings and uses: Creosote treated timber is not normally used in domestic buildings because of unpleasant and irritating odour. Timber used for domestic purposes is treated with water-borne chemicals by using pressure treatment or with organic solvent preservatives by double vacuum method. Wood treated with both creosote and water-borne preservatives is used as transmission poles, in warehouses and industrial and agricultural buildings.

Greenhouses, Seed and Mushroom Boxes: The timber treated with creosote or PCP are not recommended and the CCA processed timber can be used.

Children Playground Equipment and Garden Toys: Water-borne preservatives fixed in the wood can be used with absolute safety. Deposits seen on the surface are removed by redrying the wood to 22% moisture content, hosing down and drying again. Two coats of a water-repellent finish are also recommended as precaution. Creosoted wood is unsuitable.

Animal Pens: Most of the preservatives can be used with safety for animal pens. Timber treated with creosote should be air-dried and deposits on the timber treated with water-borne salts should be removed as described above. The use of PCP in preservatives should be avoided.

Food Containers: Creosoted timber must not be used as food containers. Copper 8-quinolinolate is recommended for the containers. The preservatives fixed in the wood, such as CCA, can be used with absolute safety on condition that surface deposits should be removed as described previously.

Typical overall average preservative retention for various uses of timber

Situation/Hazard	Timber Product	Retention (kg/ml) Creosote	CCA salts
Interior timbers	Roofing timbers joinery, etc.	50	6
Exterior timbers not in ground contact	Exterior building, timbers, cladding, bridge, railings, etc.	60	8
Timber in ground contact	Transmission poles, railway sleepers, fenceposts,etc.	100	12
Timbers frequently or permanently immersed in fresh water	Bridge piling, cooling towers, etc.	120	16
Timbers frequently or permanently immersed in sea water	Groynes, jetties, boat building timbers	150	24

3. WOOD BASED INDUSTRIES

3.1 A panoramic view of the forest based industries in India

Any industry which depends on forests for their raw material requirement is considered to be forest or wood based industry. India is one of the leading countries with mushrooming of wood based industries which include pulp and paper, match, saw wood, veneer and plywood, pencil and dendro biomass industries.

The forest based industry is growing rapidly with the increasing demand for furniture, housing, construction material, packaging, agriculture good, sports goods, plywood, veneer, matches etc. Similarly the biomass based power generation industries are also on the raise across the country to generate electricity from forest biomass. This growing demand of wood and wood based industries will create a wood deficit of 20-70 million cubic meters by 2020.
It is estimated that approximately 40 per cent of the forest products are supplied from outside forest areas and more than 95 per cent of fuel wood and major timber requirement are obtained from outside forest areas. Section 4.1.1.d of New National Forest policy of India suggest to Increase the productivity of forest plantations to meet the require of forest based industries. It says Productivity of the forest plantations are poor in most of the States. This will be addressed by intensive scientific management of forest plantations of commercially important species like Teak, Sal, Sisham, poplar, Gmelina, Eucalyptus, Casuarina, Bamboo etc. The lands available with the forest corporations which are degraded & underutilized will be managed to produce quality timber with scientific interventions. Public private participation models will be developed for undertaking Afforestation and reforestation activities in degraded forest areas and forest areas available with Forest Development Corporations and outside forests.

Section 4.4 Facilitate forest industry interface. There is a need to stimulate growth in the forest based industry sector. This sector being labour intensive can help in increasing green jobs. Forest corporations and industrial units need to step up growing of industrial plantations for meeting the demand of raw material. Forest based industries have already established captive plantations in partnership with the farmers. This partnership needs to be further expanded to ensure an assured supply of raw material to the industries with mutually beneficial arrangements. Further a forum for interaction and collaboration would be set up for Forest based industries with forestry institutions and concerned stakeholders so that a demand for trained professionals is created in the sector.

3.2 Demand and supply position of raw material for wood based industries

Production of Wood in India

The information on production of wood and timber in India is scattered. As per the estimates of Forest Survey of India (2011), while the annual production from the natural forests is quite low, the production from the TOF is much higher. The Forest Development Corporations (FDCs) have been producing the major part of the total timber produce from the government forests with approximately 65-66% of according to the estimation from the available figures. Most of the industrial wood in India is produced from outside government forests and agro forestry/farm-forestry in the country. Interestingly, a large section of total production of Industrial wood in India’s sourced from unknown or unregistered sources (more than 35%). Such sources may include illegally harvested wood and reclaimed wood. Imports contribute about 8% among round wood sources.

Pruduction of timber in India (Millioon Cubic Meters per year)

Sources of Wood in India	Volume (million cum)
Total Estimated Production of Wood from Natural Forests	3.175
Annual Production of Wood from Trees outside Forests (TOF)**	44.34
Total	**47.51**

Sources: State of Forest Report, Forest Survey of India, 2011, ** Forest Sector Report India, ICFRE, 2010

As far as the consumption of wood is concerned, fuel wood alone amounts to be approximately 90% of the total wood production in India. Maharashtra and Uttar Pradesh have had the largest share in the domestic consumption of timber wood, with little over 30% combined, in 3 major industrial sectors for wood consumption –House construction, Furniture and Agricultural implements(FSI, 2011).

Consumption of wood in India

Consumption Category	Units	Value
Construction, Furniture and Agricultural Implements (RWE)*	Million Cubic Meters	48
Plywood and & Panel**	Million Cubic Meters	8.3
Paper, paperboard and newsprint***	Million Metric Tons	8.7

Source: *SFR 2011 Forest Survey of India
** Association of Furniture Manufacturers and traders (AFMT)
***CPPRI, 2016

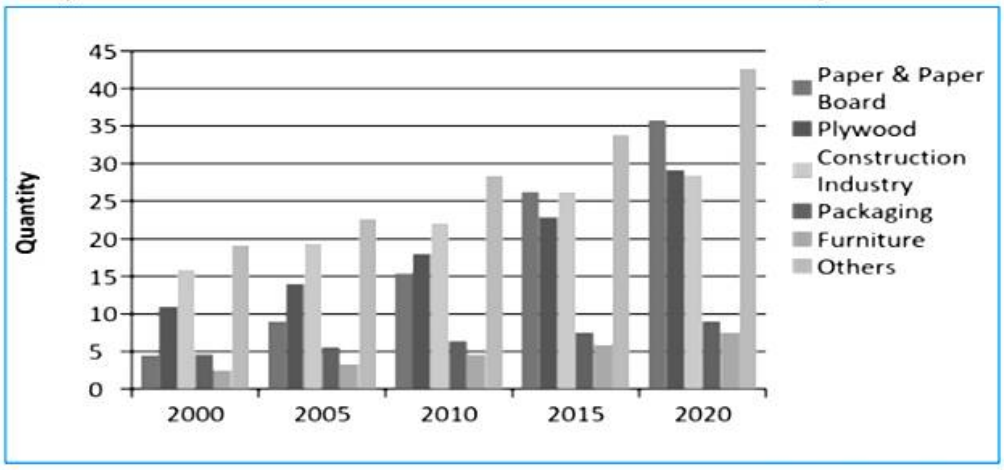
Fuel wood consumption in India

Total Fuelwood consumption	Million Tons	216.42
Fuelwood Consumption from forests	Million Tons	58.75

Source: SFR, Forest Survey of India, 2011

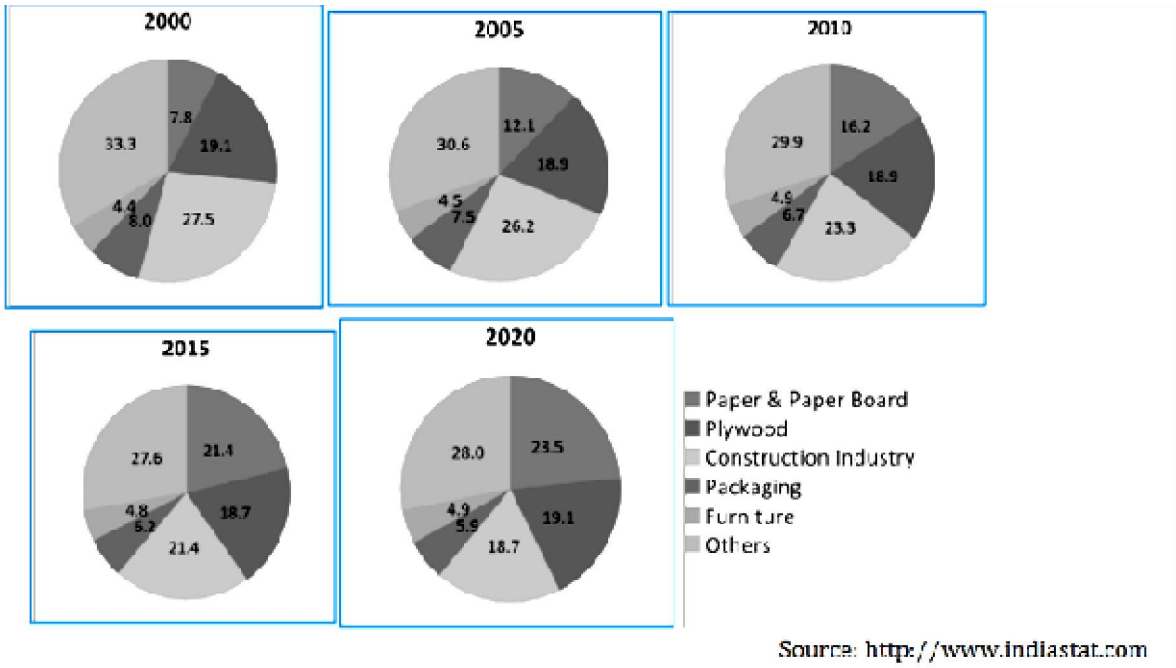
Projected Wood Demand and SupplyThe Paper & Paperboard, Construction and Plywood industries have been projected to be the largest wood-based industries in India by demand. The total Projected Demand of Raw-wood by different industries in India (2000to 2020) is given in the Figure below.

Projected Demand of Raw-wood for different Industries in india



Source: http://www.indiastat.com

Projected demand (percent) of wood by major industrial segments.



Source: http://www.indiastat.com

The projected demand for wood by different industries:

Industry	Year						
	1998	1999	2000	2005	2010	2015	2020
Paper & Paperboard	4.48	4.48	4.48	8.96	15.4	26.24	35.84
Newsprint	1.46	1.63	1.78	2.56	3.42	4.63	6.22
Rayon Grade Pulp	2.1	2.3	2.5	2.8	3.1	3.4	3.8
Construction Industry	13.6	14.6	15.9	19.4	22.1	26.3	28.5
Packaging	4.36	4.49	4.62	5.54	6.4	7.55	9
Furniture	2.25	2.38	2.52	3.36	4.62	5.9	7.53
Automobile Industry	0.17	0.18	0.19	0.28	0.41	0.6	0.87
Agricultural Implements	2	2.06	2.12	2.33	2.5	2.5	2.5
Railway Sleepers	0.04	0.04	0.03	0.02	0.02	0.02	0.02
Sports Goods	0.27	0.31	0.35	0.58	0.98	1.67	2.73
Handicrafts	0.4	0.42	0.45	0.54	0.65	0.78	0.95
Plywood	10.1	10.5	11	14	17.96	22.9	29.2
Veneer	0.25	0.26	0.27	0.34	0.43	0.54	0.7
Particle Board	0.13	0.13	0.14	0.18	0.22	0.28	0.35
MDF Board	0.13	0.14	0.14	0.17	0.21	0.24	0.28
Match Box	2.1	2.2	2.3	2.6	3	3.4	4
Mining	2.9	3	3.2	3.5	4	4.5	5
Catamaran	0.03	0.03	0.03	0.05	0.07	0.11	0.16
Miscellaneous	.5.14	5.4	5.7	6.7	9.4	11.2	15.15
Total	**51.9**	**54.55**	**57.72**	**73.9**	**94.89**	**122.8**	**152.8**

Source: www.indiastat.com

Estimated production of paper, Paperboard and Newsprint

Million Tonnes	2010-11	2011-12	2012-13	2013-14
Capacity	12.7	13.55	13.9	18.4
Domestic Production	10.1	10.9	11.8	14.49
Exports	0.53	0.55	0.58	0.56
Imports	1.58	2.34	1.98	2.58
Domestic Market/Consumption (Production + Imports - Exports)	11.15	12.69	13.2	16.51

Source: Indian Paper Manufacturers Association, 2014

The shortage of raw materials for the paper and pulp industry in India has always been the norm, and has been a major challenge for the industry; Government regulations and technical issues being the other obstacles (Johnson, 2011)

India being a net importer of wood and wood based panel products, imports around 7-8 billion USD worth of wood and wood products each year causing huge fiscal deficit. Among all the wood product types, wood-logs of long-rotation trees are preferred by the Indian manufacturers of wood based products. The prominent countries exporting wood logs to India are Malaysia, Myanmar, Indonesia, Nigeria, Ivory Coast, Ghana, Togo, Gabon, Brazil, Panama, Costa Rica, Ecuador and New Zealand (Adams, ITTO).

Import status of forest product at national level

Year	Wood based Products	Pulp & Waste Paper		Newsprint		Paper boards and manufacturers		Printed books, manufacturers and journals	
	Value (in Rs. Lakhs)	Qty (in ton)	Value (in Rs. Lakhs)	Qty (in ton)	Qty (in ton)	Value (in Rs. Lakhs)	Qty (in ton)	Value (in Rs. Lakhs)	Qty (in ton)
2009	523983.09	2060649	286350.42	611685	160649.44	599510	369855.81	171231	93241024.9
2010	912572.75	3586497	600749.91	1176592	338468.2	2922159	538640.29	192515.79	146315258
2011	1052177.67	2719335	576914.27	1341122	452626.83	1215162	726163.15	331669.35	356696711.1
2012	1341148.7	3305663	687136.11	1237076	443006.19	1301780	818195.41	369249.68	260742436.1
2013	875756.88	2097320	439976.97	733776	258106.13	881644	517338.41	187809.61	159965566.5

Source: Yadav and Basera 2013. Indian Institute of Forest Management

Mainly wood is imported in India in raw form and exported as value added products. The major categories of timber, which are being traded by India at the International market are Plywood, Wood logs (Industrial Roundwood), Veneer, Sawn Wood, Fiber Board andParticle Board.

Average value of import and export

Trade value and quantity		Plywood	Sawn Wood	Veneer	Fibreboard	Particle Board
Imports	Value (Million $)	42.4	80.4	37.1	49.0	33.6
	Quantity ('000 tons)	34.9	133.05	60.74	104.2	78.51
Exports	Value (Million $)	8.3	14.8	14.6	7.7	2.7
	Quantity ('000 tons)	14.7	20.6	10.5	9.7	2.7

Source: www.dgft.nic.in

The plywood imports showed peak in 2011.The total value of plywood imported in 2011 increased by more than 100% in 2010. The quantity of plywood imported also increased in the similar proportion from about 48,000tons in 2010 to 103,000tons in 2011. The price per ton of all plywood imported has been increasing with moderate margin since then. The overall proportion of India's Plywood imports by value has been only 3% of the total timber imports and 8% by quantity of the world. The proportion of Plywood exported by India is among all timber product categories is about 4% by value

China has been the largest exporter of plywood to India from 2001 till date. UAE and Turkey lead other countries in importing plywood from India. Malaysia has been the top exporter of wood logs to India followed by New Zealand, Ivory Coast, Papua New Guinea and Ghana. Leading countries exporting sawn wood to India are Germany, Indonesia, Tanzania and the USA. In 2015, Germany's exports of sawn wood to India were all time high at $48 million. Since 2011, Germany has been the top exporter of sawn wood to India. India's exports most of its sawn wood to UAEafter2010. The other major importers of sawn wood

from India are Belgium, Kuwait, Italy and the USA.Myanmar, Viet Nam and China have been the leading exporters of Veneer to India. Large scale imports of Veneer by India started only in 2014, and thesethree countries had largest share in veneer exports to India.USA, China and Nepal are the biggest importers of veneer from India. However, India exports just over half of its total veneer to the top 10 countries which import veneer from India.

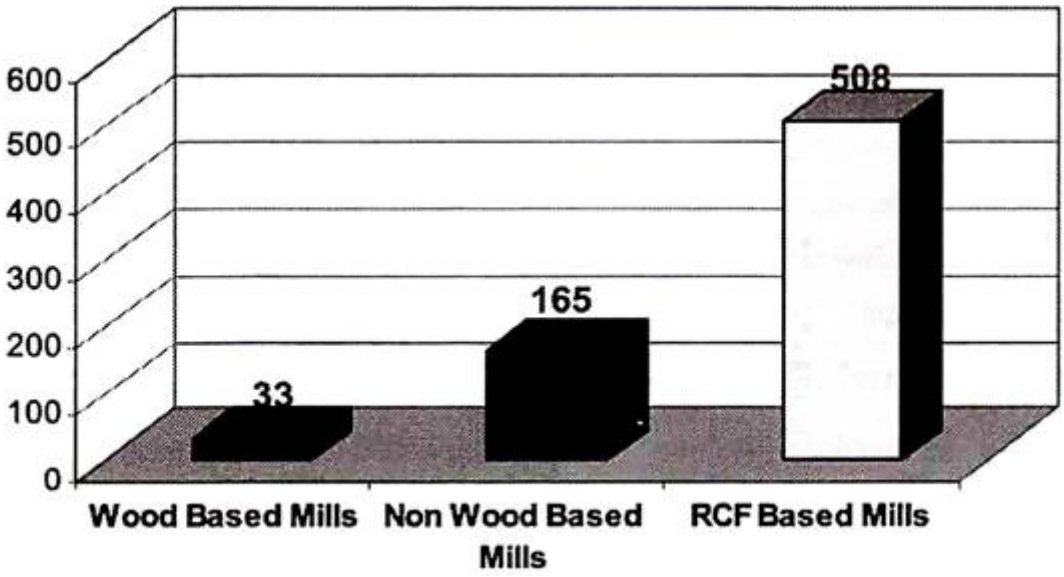
There has been a growing demand for fiberboards (particle board and Medium Density Fiberboard-MDF) in India, as growth of organized/mechanized furniture manufacturing and consumption has peaked up in last decade. Malaysia, Thailand and Sri Lanka have been the leading exporters of Fibreboard to India. Although Malaysia has been the largest exporter of fibreboard to India. Thailand has overtaken Malaysia in being the largest exporter of Fibreboard to India in the last three years. Fibreboard worth more than $700million wereimported by India during 2001-15 from all over the world.Middle Eastern countries of UAE, Saudi Arabia and Qatar have been the leading importers of fibreboard from India with collective imports worth about $65million during same period. These three countries collectively have imported more than 72% fibreboard from India during the same period.
Top four species of long rotation tree/timber species imported by India are Teak (Tectonagrandis) ,Gurgan (Dipterocarpus alatus), Red Shorea spp(including Sal.) ,and Beech (Fagusspp.). Teak is most favoured species and imported mainly from Ghana, Ivory Coast, Equador and Costa Rica. Since 2013, teak imports by India have declined by more than 30%.Myanmar has been the largest country exporting Gurgan to India. The fall in the import from 2013 to 2015 is can be attributed to Myanmar government's decision to ban logging in their forests. Malaysia has been the largest country exporting Red Meranti wood. Malaysia is the largest exporter of Sal to India, imports of which have increased since 2011.Germany has been the largest exporter of Beech wood to India, with more than half of all beech exports to India among exporting countries.

3.3 Indian tree species whose timbers are suitable for different wood based industries

1. Pulp and Paper Industries:

The pulp and paper industry is one of the key industries in India and it is highly fragmented. Today, there are about 700 paper mills in India with 33 in the large scale sector. During 1990s, the per capita consumption of paper was 3.3 kg which has now escalated to 8 kg, but still lower compared to the global average of 47.7 kg. The current production of raw material for pulp and paper production is 2.76 million tons as against the demand of 5.04 million tonnes. The shortfall is as high as 45 per cent.

The total installed capacity of pulp & paper mills in the country is estimated to be over 7.5 million tons which is likely to increase to 14 million tons by the year 2020. In India, paper is manufactured from wide range of raw material like wood, recovered paper, baggasse and other agro residues. Based on that the paper mills have been classified and furnished in Fig.



Categorization of Paper Mills Based on Cellulosic Raw Materials
(RCF-Refractory Ceramic Fiber)

Currently the paper industries in the country face serious problem in terms of raw material availability which became a major deterrent to competitiveness and growth of industry. Hence all the industries have started massive plantation programme with varying degree of success.

Major Pulpwood Species:
i. *Bamboo*
ii. Casuarina spp.
iii. Eucalyptus spp.
iv. Leucaena spp.
v. Acacia spp.
vi. Populus spp.

2. Match Industries:

Match wood industry is one of the oldest wood based industries in India. About 75 per cent of the total match wood industries in the country are located in the state of Tamil Nadu which comprises nearly 6,000 match industries with mechanized, semi mechanized and as cottage industry. The per capita consumption of matches in India increased steadily from 2.45 kg (1970) to 4.25 kg (1987).

The current per capita consumption rose to 6.0 kg which is more staggering. The increasing demand for the matches coupled with declining wood resources is a major bottle neck faced by the entire match industries in India including the ancillary splint and veneer industries. In fact, there was a short fall of 9,00,000 m^3 in the year 2000. The veneer quality wood for match boxes, which accounts for 44 per cent of match wood used, is also in short supply.

Major Matchwood Species:

i. *Ailanthus excelsa*
ii. Albizia falcataria
iii. Alianthus triphysa
iv. Albizia lebbeck
v. Anthocephalus cadamba
vi. Erythrina indica
vii. Populus spp.

3. Timber and Sawn Wood Industries:

Traditionally people in the country predominantly use timber and other converted wood in their entire domestic and industrial wood requirement. The rapid population growth, urbanization and industrialization resulted in greater usage of wood in furniture, housing and construction material. During, 2010-2012 more than 500 million square feet of space is estimated to be built in urban areas of the country and the wood products were valued around US Dollar 3 billion.

With greater usage wood as a predominant material for housing and construction material in urban and semi urban areas there is going to be a great demand for timber and other sawn wood requirement. The Indian furniture market is estimated at 8 billion US Dollar and in most cases raw materials are imported from various countries.

Major Timber Species:

i. *Tectona grandis*
ii. Terminalia spp.
iii. Albizia spp.
iv. Gmelina arborea
v. *Azadirachta indica*
vi. Pterocarpus spp.
vii. Mangifera indica
viii. Artocarpus spp.
ix. Dalbergia spp.
x. Dipterocarpus spp.
xi. Eugenia spp.

4. Plywood Industries:

One of the fastest growing in India is the plywood industry. The industrialization and urbanization and the increased interest on interior decorations have made great usage of plywood in the country. Wide range of species have been found amenable for making face, core and inner veneers resulted in establishment of more than 2,000 small scale industries involved in plywood manufacture.

The liberalization and privatization policy of government of India also significantly contributed towards establishment of new rural industries. These industries also depend heavily on various species which thereby attracted large scale promotion of plywood based industrial wood plantations.

Major Plywood Species:

i. *Populus spp.*

ii. Melia dubia
iii. Paulownia spp.
iv. Eucalyptus spp.
v. Ailanthus spp.

5. Particle Board Industries:

Particle board is reconstituted constructional panel particularly developed as a substitute for natural constructional wood and is made from low grade waste woods or from ligneous agricultural residues. These particle boards are predominantly used for wall paneling and interior decorations in domestic and industrial wood sector. In India, the first particle board industry was set up in late 1950s at Sitapur in Uttar Pradesh and from then onwards large number of industries has been installed across the country.

Major Raw Materials:

i. All types of wood waste
ii. All types of pine needles
iii. All types of Casuarina needles
iv. Ligneous agriculture residues

6. Fibre Board Industries

Fibre board is constituted using sheet materials of widely varying diversities manufactured from refined or partially refined wood fibers or other vegetable fibers.

7. Dendro Biomass Power Generation Industries:

Biomass is an important fuel source in overall energy scenario. Biomass is produced through chemical storage of solar energy in plants and other organic matter as a result of photosynthesis. This biomass include plantation that produces energy crops, natural vegetable growth and other organic waste and residues.

Among all these biomass, the role of dendro biomass is very significant due to their higher calorific value and increased fuel efficiency. Hence, large number of dendro biomass based power plants has been established across the country to generate electricity.

Major Energy Crop:

i. *Prosopis spp.*
ii. Acacia spp.
iii. Albizia spp.
iv. Dalbergia sissoo
v. Leucaena leucocephala
vi. Casuarina equisetifolia
vii. Eucalyptus spp.
viii. Gliricidia spp.
ix. Ceasalpinea spp.
x. Chuckrassia spp.
xi. Other hard woods

8. Oil and Biodiesel Industries:

The demand for edible and non-edible oil is continuously on the rise due to industrial and economic development. But there is no concomitant effort to augment the production

potential of oil seeds in the country. This resulted in a massive import of nearly 46 per cent of edible oil till the recent past thus claiming huge amount of country's exchequer. Similarly the crude oil requirement in the country is also increasing due to development in transport and industrial sector.

Till the recent past the consumption of crude oil was about 184.68 million tones and the rate energy consumption is increasing at the rate of 6.5 per cent per annum. India's share of crude oil production is about one per cent of total world crude oil production while in consumption its share is about 3.1 per cent of total world consumption which necessitated massive imports of crude oil.

The import of crude oil has increased from 63 per cent in 1971-1980 to nearly about 80 per cent in 2007-2008 which is an alarming issue for the country and warrants development of alternate renewable resources. Under such circumstances, efforts have been taken by various departments of Government of India to promote non edible oil seeds in the country to augment the vegetable oil feed stock to generate biofuel.

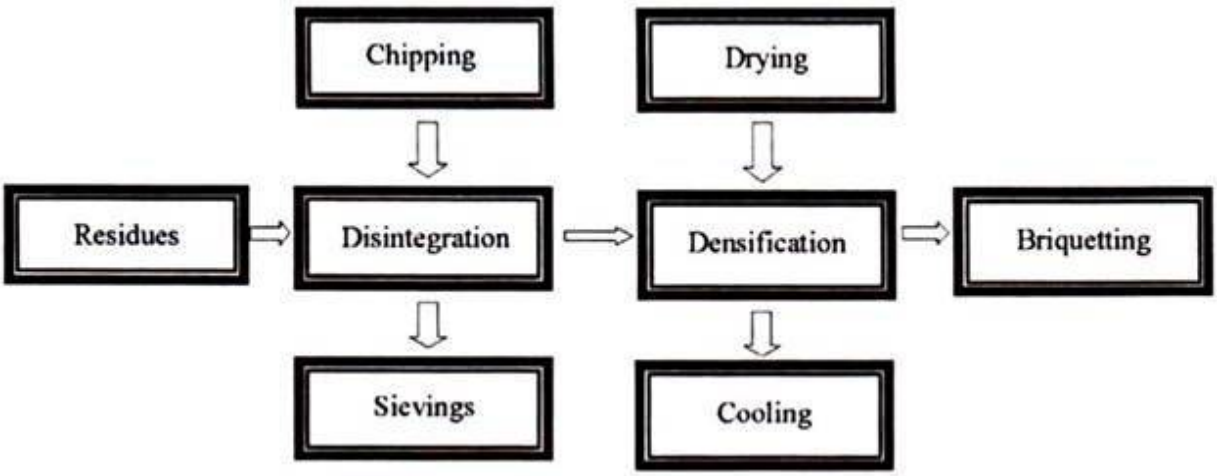
Simultaneously large number of private sector oil and biodiesel production industries has been established across the country but for want of sustainable raw material resource availability these industries are under great threat. This facilitated promotion of tree borne oil seeds across the country and their inclusion under farm and agroforestry system.

9. Value Addition Industries:

The wood based industries have to store the harvested raw materials during rainy season in order to have sustainable raw material availability and to sustain the industrial process during lean season. The post-harvest management of huge volume of industrial wood necessitates proper handling, storage and utilization which demand a scientific intervention in order to reduce post-harvest losses due to biological agents particularly powder post beetles and pin hole borers.

These biological agents are taking heavy toll of stored industrial raw materials which need to be addressed. Hence large number wood seasoning and preservative industries have been established to avoid post-harvest losses. Similarly, the plantation and industrial processing activities accounts for 20-30 per cent of wood residues which are either unutilized or underutilized for want of suitable recycling technologies.

These plantation and industrial wood residues have been successfully value added into briquettes and as on today many industries have been established across the country and successful value addition using plantation residues have been evidenced. These value added briquettes acted as excellent feed stock for biomass power generation industry, boiler industries and other industries requiring biomass for meeting the energy demands. The entire value addition process of plantation residues is depicted in the fallowing figure.



Value addition of plantation residues through briquetting

3.3.1 Plywood, fibreboard , particle board , Improved wood

Plywood:

Plywood is a material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another. It is an engineered wood from the family of manufactured boards

Smaller, thinner, and lower quality plywoods may only have their plies (layers) arranged at right angles to each other. Some better-quality plywood products will by design have five plies in steps of 45 degrees (0, 45, 90, 135, and 180 degrees), giving strength in multiple axes.

Properties

Strength

Plywood is a laminate, with multiple layers of wood chips and shavings laid on top of each other and glued together. The strength of the laminate is enhanced by the arrangement of each layer so the grain of the wood alternates, making most types of plywood stronger than an equivalent piece of the same real wood. Plywood is also about twice as resistant to sheering as regular wood.

Cost

Because plywood is made of wood chips and shavings, it can come from the parts of trees that are not suitable for the milling of beams, blocks and boards. As a rule, that makes plywood cheaper than its equivalent in real wood as well, particularly for large-scale applications.

Stability

The alternating grains and use of adhesives in plywood make it as stable or more stable than regular wood. Plywood is sometimes less prone to absorb and/or release moisture, and when it does, the alternating grain pattern resists expansion and shrinkage. As a result, the wood is sometimes more resistant to shrinking and warping.

Flexibility

Because plywood is a manufactured product, it is not limited in the same way real wood is by the size, shape and appearance endowed by nature. Plywood sheets come in a range of thicknesses and, as previously noted, with a wide range of facings as well. Plywood with a smooth veneer can be finished with many of the same finishing products used on real wood.

- Raw Materials for ply wood
- Plywood can be made from several different types of wood, including hardwoods and **softwoods**. Common hardwood trees used for plywood production include ash, maple, mahogany, oak and teak, while **softwoods** include Douglas fir, pine, spruce and redwood.

  Decorative (Ornamental) ply wood
  Tectona grandis.
  Dalbergia sissoo
  Pteroarpus dalbergioides
  Swietenia macropylla
  *Toona iliat*a

  Tea chest ply wood
  Vateria indica
  Mahilus macaranta
  Lopopetalum wightianum
  Palaquim eleptium
  Mangifera indica

  Other ruses
  E.grandis
  Melia dubia
  E. teritiornis
  Grevilia robusta
  Face veneers
  Dipterocarpus indicus
  Tectona grandis
  Dalbergia latifolia

Veneer Cores are comprised of an odd number of wood **veneers** laminated in alternating grain directions to achieve the desired panel thickness. A thin panel may consist of one **core veneer**, while a very thick panel might have 23 or more **veneers**.

face veneer. (materials) Wood **veneer** selected for its decorative qualities rather than its strength.

As Face Veneer lays the first impression of the quality of Plywoods, Flush Doors or Block Boards, Core Veneer defines the actual strength and durability of the Plywood and Flush Doors. Core Veneer from hardwoods like Gurjan

Veneer is a thin slice of wood made by rotary cutting or slicing of the log. The appearance of veneer varies and it depends on how the log is cut.. Before the peeling process, wood must be softened in order to cut it into smooth veneer of even thickness, so the logs are soaked in 40 ^{0} C temperature water for two days. Moist, warm and debarked logs are rotary cut into thin layers called veneers after careful measuring and cutting of the logs. Long but thin slices of wood appear. The drying process as full veneer mats or clipped sheets follows for 4-5 minutes under pressure in 170 ^{0}C hot air. Wood changes dimensions when it dries or absorbs water. Therefore, to produce a stable and high quality product, drying has to reduce the moisture content to the right level prior to further processing. After drying, veneer sheets are inspected for any defects such as split-ends, knot holes, loose knots, color defects etc. and sorted by quality. The veneer sheets are then packaged or mainly sent to next working line – for producing plywood.

Plywood is a wooden panel composed of thin cross-bonded veneers glued together. For greater strength properties the veneers are usually laid crosswise. Plywood panels are composed of at least three veneer layers. After veneer sheets drying and sorting procedure, jointing in length and width, surface veneer patching the gluing process follows. Veneer sheets are run through gluing machines – roller or curtain gluing. Glue is applied on veneers, which are layed so that the stack alternates. Pressing, which at first is done by cold press and followed by hot press, occurs after gluing and stacking of the veneers. Cold pre-pressing is done to flatten out the veneers and ensure the glue is distributed across the veneers evenly. Following the hot pressing in 130 ^{0}C temperatures, the glue reaction ends and bonding is achieved. Further on boards are sent to cut-to-size, sanding and grading to ensure that the dimensional properties and quality of the boards is according to the standards and agreements. Plywood can then be overlaid with various coating materials – phenolic and plastic. Coatings improve the plywood's resistance to wear impact, chemicals and weather. Films and laminates imprinted with various patterns improve the panel's frictional properties.

Fibre boards

Fibreboard is a type of engineered wood product that is made out of wood fibres. Types of fibreboard (in order of increasing density) include particle board, medium-density fibreboard (MDF), and hardboard (HDF, HB)

Medium Density Fibreboard (MDF) is used mainly by the furniture industry, but also for interior mouldings as well as substrates for laminate flooring. The homogenous structure of the MDF board gives it good bending strength, smooth surface and good screw retaining properties, making it suitable for many different applications.

Fibreboard resins offer extremely low emissions, moisture resistance, fast cure, tolerance to different wood species and variations in fibre humidity.

Fiberboard manufacture begins with wood chipping: fresh or recycled wood material is cut and sorted to small pieces of similar size. Chips are washed to remove things such as dirt and sand. Metal scraps such as nails can be removed with a magnet placed over a conveyor belt on which the chips move forward. In the case of, for example, MDF (medium density fiberboard) and not particle board, chips are then steamed to soften them for defibration. Small amount of paraffin wax is added to the steamed chips and they are transformed into fluffy fibers in a defibrator and soon afterwards sprayed with adhesives such as urea-formaldehyde (UF) or Phenol formaldehyde resin (PF). Wax prevents fibers from clumping together during storage. Chips in the case of particle board are also sprayed with a suitable adhesive before the next steps. Fibers or chips are arranged into a uniform "mat" on a conveyor belt. This mat is pre-compressed and then hot-pressed. Hot-pressing activates the adhesive and glues the fibers or chips together. Board is then cooled, trimmed, sanded and maybe veneered or laminated.

Raw materials

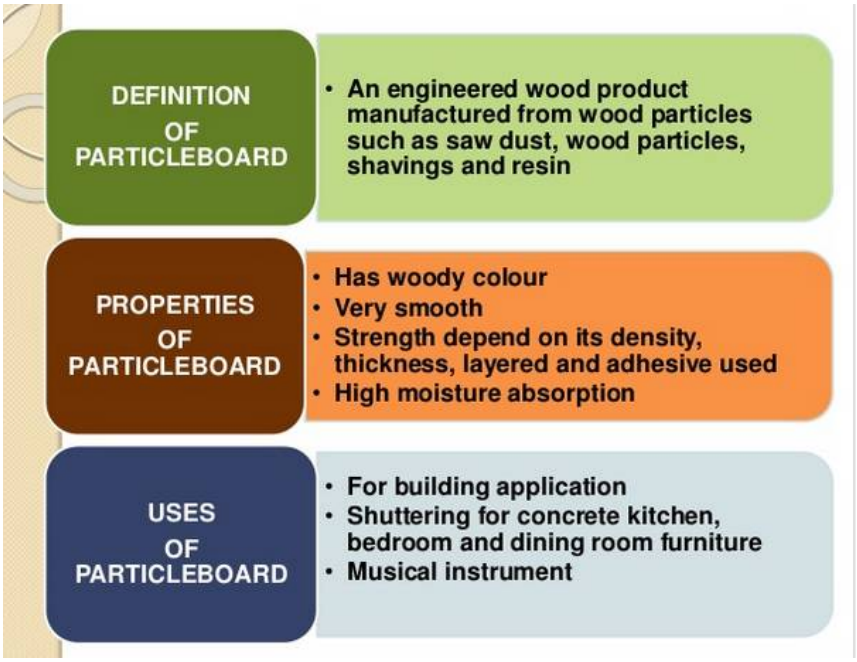
For wet process

1. Saw dust is not suitable raw material for wet formed hardboard.
2. Shavings will produce at best a marginal board.
3. The incorporation of bark will power the strength and detract from appearance of the board.when the bark content is not in excess of 15% the above factor may be disregarded, but regardless of any of these factors the bark content must be controlled to prevent a flaky,dusty, wire-side surface
4.Most woods are wood waste , such as trim ,edging ,slabs, and veneer scrap are suitable raw material for hard board.

For dry process

Saw dust shavings are suitable raw material for dry-formed board

Particle board



The market for particle board in India is expected to register a CAGR(Compound annual growth rate) of 11.21% during the forecast period (2019-2024). Major factor driving the market studied is the increasing demand for furniture in the office space and hospitality sectors. However, the increasing usage of medium-density fiberboard (MDF) is expected to hinder the growth of the market studied.

In the raw material segment, wood dominated the market in 2018, and is expected to grow during the forecast period. However, bagasse is expected to exhibit the fastest growth in the coming years.

Upcoming construction and infrastructure projects in the country are likely to act as an opportunity in the future.

Raw materials used in the manufacture of particle board

Wood	Saw dust
Bagasse	Shavings
Other raw materials	Flakes
	Chips

Application	Construction
	Furniture
	Infra structure
	Other applications

Increasing Demand for Furniture from the Office Space and Hospitality Sectors

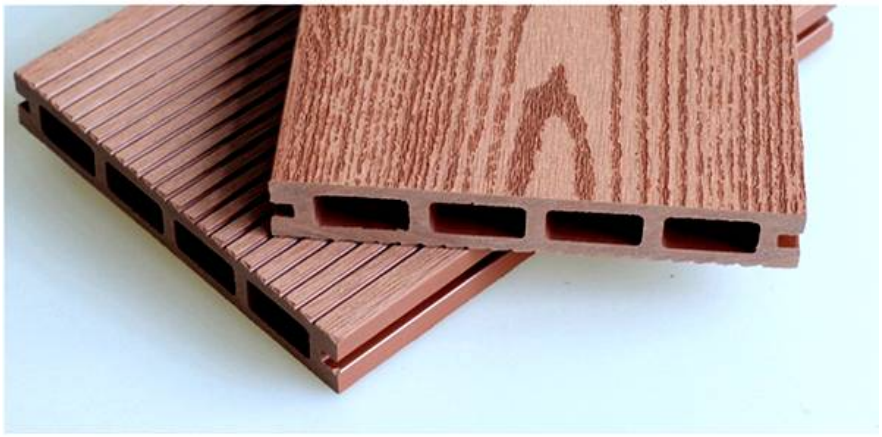
- Office space leasing in the country has increased by about 10%, crossing over 20 million sq ft in the first half of 2018. Office leasing in top eight cities increased by 60% during the period (2013-2017).

- With the demand from technology, e-commerce companies, and banking-financial services, the office space requirement in India is significantly rising, resulting in the construction of new offices. Bengaluru city is leading the office demand and supply activity in the country.
- Contribution of the travel and tourism sector to the capital investment in India is likely to increase by 6.7% per annum, during 2018-2028.
- Increase in the demand from the office space and hospitality sector projects, coupled with several government initiatives and investments, is likely to significantly boost the furniture market's growth.

Wood Composite – The Alternative, Sustainable Solution to Timber

Wood composites include a range of different derivative wood products, all of which are created by binding the strands, fibers or boards of wood together. It's also known as manmade wood, manufactured board or engineered wood, as well as wood-plastic composite (WPC) when using wood fibers and thermoplastics. Similar composite products can also be made from vegetable fibers using lignin-containing materials such as hemp stalks, sugar cane residue, rye and wheat straw, with chemical additives enabling the integration of polymer and wood flour while helping facilitate optimal processing conditions

They are fixed using adhesives and are engineered to certain specifications, resulting in a material that can have diverse applications. But the best part about wood composites is that they can be created using wood waste materials and smaller trees, reducing the need to fell old-growth forests



Wood composite manufaturing

Wood composite is usually made from the same hardwoods and softwoods used for lumber, except using the sawmill's scraps and wood waste, and created by mixing ground wood particles with heated thermoplastic resin. Some combine and process the materials into pellets which are re-melted and formed into the final shape, while others create the final product by a one-step mixing and extrusion process

Both virgin and recycled thermoplastics are used, with polyethylene-based products the most common. UV stabilizers, colorants, coupling agents and lubricants can also be added to create a product specifically targeted to its application, with both solid and hollow shapes formed.

Wood-plastic composites (WPCs) are produced by thoroughly mixing ground wood particles and heated thermoplastic resin. The most common method of production is to

extrude the material into the desired shape, though injection molding is also used. WPCs may be produced from either virgin or recycled thermoplastics including HDPE, LDPE, PVC, PP, ABS, PS, and PLA. Polyethylene-based WPCs are by far the most common. Additives such as colorants, coupling agents, UV stabilizers, blowing agents, foaming agents, and lubricants help tailor the end product to the target area of application. Extruded WPCs are formed into both solid and hollow profiles. A large variety of injection molded parts are also produced, from automotive door panels to cell phone covers.

Use of wood composite products

Composite wood products can be used in a variety of different ways, including both home and industrial construction, and is often used to replace steel for joists and beams in building projects. Their most widespread use, however, is in outdoor deck flooring, but they are also popular for railings, fencing, benches, window and door frames, cladding and landscaping work.

While composite wood can be used in most applications traditionally using solid wood, it is also a popular material for making flat-pack furniture due to its low manufacturing costs and light weight properties

Plywood is considered the original composite wood product, manufactured from sheets of cross-laminated veneer which are bonded with moisture-resistant adhesives under heat. Fiberboard is another, made by combining wood fibers with wax and a resin binder under high temperatures and pressure, while particle board is manufactured from wood chips or sawmill shavings pressed with a synthetic resin.

Oriented strand board is made from strands of wood arranged in layers and bonded together using moisture-resistant adhesives. These are then cross-oriented to give the panel strength and stiffness. Laminated timber is created using dimensional timber glued together into structural columns or beams, while laminated veneers bond thin wooden veneers into a large billet which can be used for rafters, beams, columns and joints

Advantages of wood composite

One of the main advantages of wood composite is that because it is man-made, it can be designed for specific qualities or performance requirements. It can be made into different thicknesses, grades, sizes and exposure durabilities, as well as manufactured to take advantage of the natural strength characteristics of wood (and sometimes results in a greater structural strength and stability than regular wood).

As a result, it can be used in a diverse array of applications, from industrial scale to small home projects, and enable more design options without sacrificing structural requirements. Composite wood is also easy to work with using regular tools and can be efficiently cut, fastened and drilled using basic skills. It is easily malleable and can be molded into almost any desired shape. Plywood, for example, can be easily bent to create a curved surface, without compromising its strength. It can also be manufactured into large panel sizes meaning that builders don't have to install numerous smaller pieces.

Composite wood is also less likely to fade or warp over time and far more resistant to rot, decay and marine borer attack than solid wood. It means you don't have to put as much energy or money into maintaining it over time, reducing the overall costs of the material. Wood composites also tend to be cheaper than high-quality solid wood due to the affordability of wood scrap material and the manufacturing process.

It can be manufactured in a variety of colors, eliminating the need for paint, and with a comparable appearance and feel to timber. You can choose the style that suits exactly what you want, often with wind and UV resistant properties.

But one of the main advantages of composite wood is its environmental impact, as it can be produced from smaller trees when compared to solid lumber and doesn't require the felling of large, old-growth forests. It can also be made from wood that has defects and would otherwise be discarded, as well as species that have not traditionally been used for solid wood.

But its environmental impact depends largely on the ratio of renewable to non-renewable materials used in its construction, with petroleum-based polymers having a negative impact because of their reliance on non-renewable raw materials.

Disadvantages of wood composite

Despite its environmental advantages, some wood composite does require more primary energy for its manufacture when compared to solid lumber. Some particle and fiber-based composite woods are also not suitable for outdoor use as they can absorb water and be more prone to humidity-induced warping than solid woods.

Another concern regarding wood composites is the adhesives used in their design with some resins releasing toxic formaldehyde in the finished product (particularly those made with urea-formaldehyde bonded products which is one of the cheapest and most common adhesives). The plastic materials often used in the creation of wood composites also have a higher fire hazard when compared to solid wood products, due to their higher chemical heat content and melting properties.

Consumers should keep in mind that not all wood composites are created equal (with different materials and ratios) and you do get what you pay for. It's better to invest in a high-quality composite material that will endure the elements over time and recreate the natural warmth of solid wood than a cheap alternative.

Issues

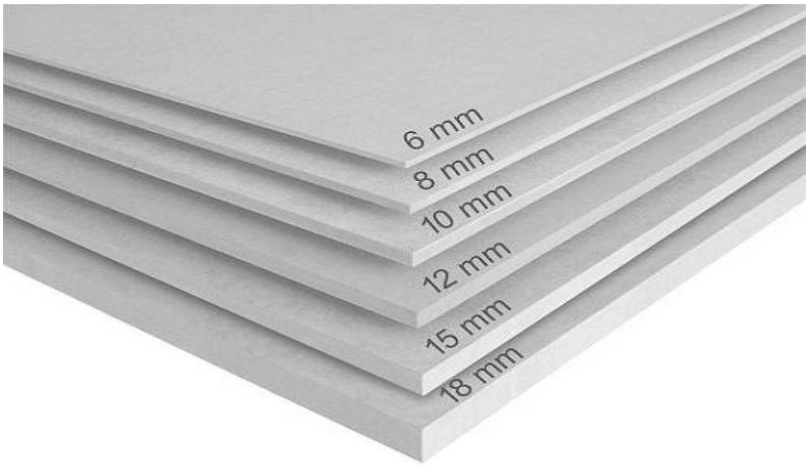
Environmental impact

The environmental impact of WPCs is directly affected by the ratio of renewable to non-renewable materials. The commonly used petroleum-based polymers have a negative environmental impact because they rely on non-renewable raw materials and the non-biodegradability of plastics.

Fire hazards

The types of plastic normally used in WPC formulations have higher fire hazard properties than wood alone, as plastic has a higher chemical heat content and can melt. The inclusion of plastic as a portion of the composite results in the potential for higher fire hazards in WPCs as compared with wood. Some code officials are becoming increasingly concerned with the fire performance of WPCs.

Cement Bonded Partical Board



Fire, Moisture, Termite & Weather Resistance

Cement Bonded Partical Board (CBPB) is fire, weather, & termite resistant a good sound insulating material, dimensionally stable, possesses a smooth surface with wood workability, & is chemically stable. Tested in accordance with BS 476 - Fire test on building materials & structures. It is classified as a class 'O' building board with class I surface spread of flame. The board has been subjected to many cycles of soaking, freezing, & heating without any sign of disintegration. Due to mineralization of wood particles by cement, CBPB is resistant to termite & vermin attack. It does not support fungus growth. Even untreated samples exposed to contact with the ground surface have shown no signs of rot or decay. Airborne sound reduction varies between 30 & 37 db for the frequency range of 100 - 3150 Hz according to thickness of CBPB Panel. It can also be drilled, sawn, & sanded with normal wood working tools, & can be fixed using screws & nails.

Interior & Exterior Applications

CBPB Panel is a unique all-purpose particle board that can be employed for a multitude of applications, both for interiors & exterior use. It can be used for doors, false ceilings, external & internal wall claddings, mezzanine flooring, acoustic roofs, car porch ceilings, roof underlays, interior & exterior walls, single & double skin partitions, guard rooms, duct covers, building facades, furniture, cupboards, school benches, kitchen underlay, outdoor cabins, prefab shelters, wall sidings, & more. Bison is unique among particle boards

in that it is available in a wide range of thicknesses - from 6mm to 40mm. Such a wide range contributes to it's application versatility.

CBPB is made from proven technology & has withstood the test of time by remaining as relevant today as it was four decades ago when invented. There are around 18 manufacturers worldwide & cement bonded particle boards are available across the globe. The demand for such boards has continued to remain consistent & high ever since their invention in the 1970s. In the wider cement board category, of which cement bonded particle boards are one type, there are about 90 producers worldwide.

Safe to Use & Work With no Noxious Content

CBPB contains no Asbestos or Formaldehyde. Asbestos is a known carcinogen & Formaldehyde is, highly, toxic Therefore, CBPB process dust is harmless & it is an environment-friendly product that is completely safe to work with. In the event of fire, structures made of CBPB would emit no harmlful fumes. Suffocation by noxious fumes is a leading cause of fire-related injuries & death.

Extremely Affordable & saves Time, & Labour with short times to Construction

CBPB is affordable, costing sometimes as much as the cheapest plywood available. Yet, it can completely replace wood for most applications. In addition, construction with CBPB is, extremely, time efficient. For instance, a CBPB shelter of 1000 square feet can be erected & made fit for occupation in less than eight hours. This results in additional savings in labour & transport. Further, Bison structures can be dismantled with ease & transported elsewhere.

Made of Homogenous Construction With No Layers & Available in One Consistent Quality Grade

CBPB Panel is made in one grade only with stringent quality control. Unlike plywoods & some particle boards CBPB is not available in a water proof or boiling water proof grade, fire-proof grade, commercial grade, etc. All CBPB products & its variants come with the exact same properties of fire & weather resistance, sound insulation, termite & vermin resistance, etc. CBPB is an ideal replacement for weather-proof plywood or other particle boards

Available in Multiple Appearances to Cater to a Range of Aesthetic Requirements & Taste

CBPB is available in a laminated version .This variant is available in thicknesses of 6mm, 10mm, 12mm, & 16mm in shades like Natural Teak, Light Gray, Sea Beach, & Ivory. The laminated surface is impermeable to moisture & highly resistant to staining. The surface can also be cleaned with a wet cloth.

Chemically Stable With Resistance to Dilute Chemicals

CBPB is ready for decoration & needs no surface preparation. The board can take any surface finish including lime wash, water-bound distempers, emulsion paints, laminations, foils, primers, etc. This is reflective of its chemical stability & it is also unaffected by many dilute chemicals such as brines, bleaches, detergents, & chlorine solutions.

Weight is its Strength

CBPB is a high-density product & its weight is its strength. Its density is 1250 Kgs per cubic meters &, consequently, it has high compressive strength of 15 Newtons per square mm. To illustrate, a 50 mm thick Bison panel wall made with two 10 mm thick CBPB

cladded on either side of a thin, light gauge steel framework is able to take a vertical load of 1100 Kgs plus / per foot run of its length. This is not possible with other medium or light density boards. For applications involving furniture which is not required to be moved often, Bison is both economical & durable.

Dimensional Stability

CBPB panel has excellent dimensional stability in variable ambient temperatures & humidity conditions. The swelling in thickness after 2 hours of immersion in water is 1% & after 24 hours immersion, it is only 1.5%. Likewise, longitudinal & transverse swelling is approximately 0.3% for change in relative humidity of air from 30% to 95% at 20 degrees celsius.

Worked With Any Tools

Tools like circular cutting saw machine & drill machines can work effortlessly on CBPB Panel. The wear in tools is much less on CBPB than on other resin bonded boards. This is due to the fact that resistance offered by cement is much less than resistance offered by boards made of sticky resins.

When working with hand tools, CBPB Panels may require little more effort than soft woods. But extra time taken on account of this will not be more than 10 to 15% of the time required by soft boards. However, performance wise, the durability of CBPB is 5 to 10 times more than the other particle boards.

Easy Methods of Edge Protection

Edge protection is a common problem with all particle boards. Due to its limited tensile strength (9N/sq. mm) & heavy density, CBPB also has an edge protection problem. However, this problem is easily solved by proper supports & lipping. CPBP Panel when fixed or gripped in a framework becomes tough & strong. It only requires care in handling to avoid premature damages. As a matter of fact, the ability of the carpenter to carefully handle the Panel is of more importance than the actual skills required for working with it.

Warping Can be Easily Avoided by Proper Balancing

Almost all wood-based boards warp due to change in moisture in the board. This is more so when they are subjected to an unbalanced condition. Imbalance occurs when the surface of one side of the board is covered & the surface of the other side is exposed to atmosphere. For example, when a stack of boards are left unprotected, the upper board is likely to warp because the top surface is exposed while the bottom surface is not exposed. The unprotected side of the board releases or picks up moisture according to atmospheric humidity causing warping in the board. Warping is more likely while moisture is being released from the board. This can be avoided by covering the stack with a water proof paper or cloth.

Similarly, warping occurs when a board is painted on the surface of one side & the other side is left unpainted. To avoid this, the other side & edges will also have to be painted to give an equal effect.

When the board is laminated on one side, the other side would also have to be given an equal effect, by way of painting with an impervious paint or with a cheaper lamination.

Another point to be remembered in this connection is that the painting or lamination has to be done when the board is dry. If there is excess moisture in the board, it may cause de-bonding of the laminate or blistering of the paint when it starts to release moisture in warm climate. The ability to absorb & release moisture makes the board 'non-condensing' which is important for the boards that are used in extreme climatic conditions.

3.3.2 Properties and use of plywood , fibre board and particle board

properties and use of Plywood

Followings are the properties of Plywood:

1. An alternation of the grains is done inside plywood which is called cross graining. It bears importance for some reason which increases the facility of plywood. Such as
    - Cross grainging in plywood helps to avoid the possibility to split while the edges are nailed.
    - It increases the strength of the material.
    - It helps to bind the grains more tightly.
    - Unnecessary expansion and wood shrinkage are avoidable for cross graining.
    - Gives enriched spatial stability.
    - Board consistency remains firm to all direction due to this.
2. Plywood has a reduced possibility to bend because odd numbers of plies are attached maintaining balance inside plywood.
3. The stiffness of plywood has made it hard to bend and inflexible.
4. While solid wood is heavy, furniture made from plywood are comparatively lighter to transfer.

Advantages of Plywood

1. High uniform strength - wood is 25-45 times stronger along the grain than across the grain. Crossing the adjacent sheets tends to equalise the strength in all directions.
2. Freedom from shrinking, swelling and warping - Solid wood exhibits considerable movement across the grain but generally negligible shrinkage or swelling in a longitudinal plane. The balanced construction of a plywood panel with the grain direction of adjacent veneers at right angles tends to equalise stress, thus reducing shrinkage, swelling and warping.
3. Non-splitting qualities solid wood splits fairly readily along the grain. Plywood by virtue of the crossed laminations can be nailed or screwed near the edges without damage from splitting.
4. Availability of relatively large sizes - Sawn timber can be obtained in fairly long lengths but only in relatively narrow widths. Plywood can be sold in sizes up to 6 ft * 25 ft and by the scarf jointing of small sheets up to 6 ft *40 ft, however 6 ft*3 ft is the most common size.
5. Economical and effective utilisation of figured wood - Twenty sheets of veneer can be sliced from 1 inch of solid wood, when glued to a core of cheaper material a high grade panel is produced. This procedure thus effects distinct economies in the use of figured or the more valuable woods. In addition to facilitating the utilisation of attractive but fragile face veneers to give results which cannot be duplicated in solid construction. More effective utilisation is obtained by the matching of veneer in such

a manner that the decorative effect due to the natural figure in the wood is enhanced by the regularity or symmetry of the design.

6. Dense woods can be sliced and bonded into plywood panels for use in furniture construction whereas furniture fabricated from solid timer would be far to heavy.
7. Ease of fabrication of curved surfaces - The trend of modern architectural design is to feature curved surfaces. The desired shapes can be readily fabricated in plywood construction, utilising male and female forms, or a single forming a vacuum press or autoclave
8. One of the important aspects in the manufacture of plywood is that it results in the conservation of timber by the elimination of the waste which occurs in sawing eg sawdust. Waste is confined to the small core which remain after peeling, and from the veneer which is lost in rounding up the log, and the elimination of such defects a knots and splits.

   Disadvantages & Limitation of Plywood

   Followings are the disadvantages of Plywood:

   a. Urea and phenol formaldehyde used for gluing causes cancer.
   b. Plywood is in many aspects weaker than wood.
   c. Not durable like wood.
   d. Not always easy to sculpture on this.
   e. Lighter than normal wood.
   f. Without some special resistance method maximum after long-term get attacked by insects.
   g. Plywood cannot be exposed to wet or moisture weather for a long period of time.

   h.The surface of plywood if not painted well can be peeled off.

   i.Properties and use of fibre board

Properties and use of fibre board

Fiberboard, classified by ASTM (American society of testing metrial)C208, Standard Specification for Cellulosic Fiber Insulating Board,has many benefits and is used in residential and commercial construction.

Applications include:

- sound proofing/deadening,
- structural sheathing,
- low-slope roofing,
- sound deadening flooring underlayment,

Fiberboard is also used in the automotive industry to create free-form shapes such as dashboards, rear parcel shelves, and inner door shells. These pieces are usually covered with a skin, foil, or fabric such as cloth, suede, leather, or polyvinyl chloride.

3.3.3 Sandal wood , Katha, Agar wood

Sandalwood

Santalum album, or **Indian sandalwood**, a partial parasite is a small tropical tree, and is the most commonly known source of sandalwood. It is native to southern India and Southeast Asia. Certain cultures place great significance on its fragrant and medicinal qualities. It is also considered sacred in some religions and is used in different religious

traditions. The high value of the species has caused its past exploitation, to the point where the wild population is vulnerable to extinction. Indian sandalwood still commands high prices for its essential oil, but due to lack of sizable trees it is no longer used for fine woodworking as before. The plant is widely cultivated and long lived, although harvest is only viable after many years. Etymologically it is derived from Sanskrit चन्दनं *chandanam*.

Sandalwood is a commercially and culturally important plant species especially in India belonging to the family Santalaceae. The wood is valued in carving because of its dense character. Sandalwood oil is extracted from the heartwood by steam distillation. The average yield of oil ranges from 3.0% to 6.0%. The sweet, powerful, and lasting odor has made sandalwood oil useful in the perfume industry, soaps, candles, incense, folk medicine, and religious and cultural purposes for centuries. In addition, the wood and its powder are used for religious and medicinal purposes, and the food industry, especially in India. The sandalwood tree flourishes in regions where the climate is cool with moderate rainfall, plentiful sunshine, and long periods of dry weather. The tree is planted in different states of India but large commercial cultivation state is Karnataka. The trees are slow growing and usually take about 30 years for the heartwood to become economically useful in India.

S. album has been the primary source of sandalwood and the derived oil. These often hold an important place within the societies of its naturalised distribution range. The central part of the tree, the heartwood, is the only part of the tree that is used for its fragrance. It is yellow-brown in color, hard with an oily texture and due to its durability, is the perfect material for carving. The outer part of the tree, the sapwood, is unscented. The sapwood is white or yellow in color and is used to make turnery items. The high value of sandalwood has led to attempts at cultivation, this has increased the distribution range of the plant. The long maturation period and difficulty in cultivation have been restrictive to extensive planting within the range. Harvest of the tree involves several curing and processing stages, also adding to the commercial value.

Santalum spicatum was extensively harvested and exported from Western Australia during colonisation, this was used as a less expensive alternative to this species. There are two commercial Indian sandalwood plantations in full operation based in Kununurra, Western Australia.

Sandalwood oil has been widely used in folk medicine for treatment of common colds, bronchitis, skin disorders, heart ailments, general weakness, fever, infection of the urinary tract, inflammation of the mouth and pharynx, liver and gallbladder complaints and other maladies. Recently, the *in vivo* anti-hyperglycemic and antioxidant potentials of α-santalol and sandalwood oil were demonstrated in Swiss Albino mice. Additionally, different *in vitro* and *in vivo* parts of the plant have been shown to possess antimicrobial and antioxidant properties, possibly attributed to sesquiterpenoids, shikimic acid, etc.

Katha

Khair (Acacia catechu)

Natural Habitat and Classification

Acacia catechu is widely distributed throughout the greater part of India except the most humid, cold and the driest regions. It is common in the sub-Himalayan tract and outer Himalayas ascending from 900 to 1,200 m from Jammu to Assam. The record distribution of

khair shows that the various forms of it, rather than overlapping, appear representative of none or another tolerablywell defined areas.

Var. catechu–Found chiefly in Punjab, Garhwal and Kumaon, Bihar and Orissa. In the sub-Himalayan tract and the outer Himalayas, it ascends upto 900-1200 m elevation.

Var. catechuoides–Found chiefly in Sikkim terai, West Bengal and Assam. This is the Burmese form.

Var. sundra–Found chiefly in the Indian Peninsula. This is southern and western form occurring in the Deccan, Maharashtra, Gujarat and Rajasthan

Kattha is obtained by crystallization in cold from the water extractives of the heartwood of **Acacia Catechu**, commonly known as **Khair** tree. **Acacia Catechu** is widely distributed in India , from the northwest plains to eastwards in Assam and throughout the country, particularly in drier and deciduous regions.It is obtained by boiling small chips of the heartwood in specially designed earthen pitchers and allowing the concentrate to cool and crystallize.

Katha is being produced in the country since long and it is a mass consumption item. It has medicinal values as well and is **used** in ayurvedic medicines. It cures itching, indigestion, bronchitis and is effective in treatment of leprosy, ulcers, boils, piles, and throat diseases etc.

a) Properties Including Strength Properties

Physical properties of the wood

Sapwood sharply distinct from heartwood, light yellowish-white or yellow. Heartwood deep red or reddish brown, darkening on exposure; somewhat lustrous. The wood is hard to very hard, heavy to very heavy, average weight 1010 kg/m3at 12% moisture content; somewhat coarse and even-textured and straight to interlocked grained. The wood has no characteristic smell or taste.

Mechanical properties

The timber is very strong, very hard, very steady and moderately tough. The figures for its suitability as a timber for various purposes, expressed aspercentages of the same properties of teak, for specimens from western U.P., are –weight, 147; strength as a beam, 128; stiffness as beam, 119; suitability as a post or strut, 127; shock resisting ability, 111; retention of shape, 116; shear, 155; surface hardness, 178; refractoriness (splitting co-efficient), 100; nail or screw holding property, 148.

Seasoning propertiesThe timber is highly refractory and liable to end-splitting and surface cracking during seasoning. It seasons very slowly. It should therefore, be converted soon after the rains and stacked properly under shade, well protected from rapid drying. Seasoning of thick boards or planks should be avoided wherever the timber is intended to be further converted into thinner sections.

The best results in kiln drying with this timber will be obtained by using schedule No.II for 2.5 cm thick planks and suitably increased humidity at the various moisture content steps in the schedule in case of thicker sections. Wherever practicable, slow partial air-seasoning to about 25% moisture content before finally taking up kiln seasoning should be attempted. The pith should be removed from the pieces before seas

The sapwood is not durable. The heartwood is very durable and is described by Pearson as "one of the most durable Indian woods, which is seldom, if ever, attacked by white ants and fungi". There are several records of its having lasted for centuries in temples and it has also done well in harbour works.

Working qualities

The timber is hard to saw and machine, especially if the wood is old and dry after seasoning. A heavy gauge plate saw with closely spaced teeth and shallow gullets gives the best results and stiff tools should be used in machining and turning. The timber can be turned well. The wood can, however, be finished to an extremely smooth surface and takes polish well

Use as Timber, Poles, Pulp and Paper,etc.

Though Khair is chiefly used as a source of katha and kutch, it is also a useful timber. It is much prized for posts in house construction and also for making rice pestles, oil and sugar-cane crushers, ploughs, tent-pegs, sword handles and keels and knees of boats. There is, however, a local superstition against it in parts of Uttar Pradesh on account of which it is not used in house construction.

Khair is a valuable economic structural timber, the heartwood being naturally durable. This species has been classified as "Super Group" timber suitable for large spans more than 12 m and is placed as the first choice of selection for permanent structures (I.S.I., 1962). It is eminently suitable for tools and tool handles, particularly for mallets and plane bodies.It is excellent for making spokes and hubs of wheels.

Sapwood of khair is a waste product in katha industry as it does not find at present any use except as a fuel. Since the katha manufacturers use the spent heartwood chips as a fuel in their boilers and bhattis, considerable quantity of the sapwood is literally wasted. It can be seen from the results of chemical composition of the wood obtained at the F.R.I. Dehra Dun, that the sapwood of khair trees, if collected economically, can be profitably utilized for producing bleached cellulose which will find use in multifarious cellulose based industries like CMC, cellulose acetate, ethers, and even for paper and paper boards if made available in large quantities.

Medicinal Uses

The different parts of the tree have a variety of medicinal uses, which in haemoptysis (spitting of blood). A paste of the bark is useful in conjunctivitis. The bark is reported to be useful in the treatment of snake bites.

Wood:Cutch and katha obtained from the heartwood have great medicinal value. It is cooling, digestive and a very valuable astringent, specially in chronic diarrhea and dysentery, bleeding piles, uterine haemorrhages, leucorrhoea, gleet, atonic dyspepsia, chronic bronchitis, etc. It is also useful in cases of mercurial salivation, bleeding or

ulcerated or spongy gums, hypertrophy of the tonsils, relaxation of the uvula, aphthous ulceration of the month, etc

Katha (Catechu)The most important product obtained from Acacia catechu var. catechu proper is katha or catechu. This is obtained by boiling chips of heartwood with water. In India two varieties are marketed katha or pale catechu and cutch or dark catechu. Assold in the bazaar, katha is found in irregular pieces or small square blocks of greyish colour, which on breaking show a crystalline fracture.

There is a very large internal demand for it for masticatory use in pan preparations and in medicine. Katha isregarded as astringent, cooling and digestive and is useful in sore throat, cough and diarrhea. Externally it is employed as an astringent and as cooling application to ulcers, boils and eruptions on the skin. It is an indispensable ingredient of pan preparations. In combination with lime, it gives the characteristic red colouration resulting from the chewing of pan.

Dark catechu or cutch, which is mainly obtained as a by-product of the katha industry is marketed in the form of small cubes or blocks, rusty brown or dull orange in colour and of conchoidal fracture. It is used only for industrial purposes. It is largely used for dyeing cotton and silk and preserving of fishing nets, sailing ropes and mail bags; in water softening and in the manufacture of stencils and printers ink.

Aqar wood

Not to be confused with Agalloch.

Agarwood, **aloeswood, eaglewood,** or **gharuwood** is a fragrant dark resinous wood used in incense, perfume, and small carvings. It is formed in the heartwood of aquilaria trees when they become infected with a type of mold (*Phialophora parasitica*). Prior to infection, the heartwood is odourless, relatively light and pale coloured; however, as the infection progresses, the tree produces a dark aromatic resin, called **aloes** (not to be confused with Aloe ferox, the succulent known as bitter aloes) or **agar** (not to be confused with the edible, algae-derived agar) as well as *gaharu*, *jinko*, *oud*, or *oodh* (not to be confused with bukhoor), in response to the attack, which results in a very dense, dark, resin-embedded heartwood. The resin-embedded wood is valued in Biblical Jewish perfumery and Arabic-Middle Eastern culture for its distinctive fragrance, and thus is used for incense and perfumes. The aromatic qualities of agarwood are influenced by the species, geographic location, its branch, trunk and root origin, length of time since infection, and methods of harvesting and processing.

One of the main reasons for the relative rarity and high cost of agarwood is the depletion of the wild resource. Since 1995, *Aquilaria malaccensis*, the primary source, has been listed in Appendix II (potentially threatened species) by the Convention on International Trade in Endangered Species of Wild Fauna and Flora.[4] In 2004, all *Aquilaria* species were listed in Appendix II; however, a number of countries have outstanding reservations regarding that listing.

Agarwood Usage

Agarwood, the "Wood of the Gods" has been traded and highly coveted for thousands of years. The resinous wood is used as incense, for medicinal purposes, and pure resin in distilled form is used as an essential oil as well as a perfume component. Outside its native countries, it is most widely known in the Middle East, China, Taiwan, and Japan. A strong connection exists between use, religion, and curative properties, and elaborate traditional and religious ceremonies are known around the world. Faith healers in the Middle East use it at curative ceremonies, Japanese pilgrims donate flowers and agarwood oil to Shinto-Buddhist temples, and Vietnamese religious groups are obliged to bring agarwood to ceremonies at their temples in Mekong Delta communities.

Agarwood Essential Oil – Oud Oil

Known also as Oud oil, agarwood is one of the most precious, rare and certainly most expensive essential oils in existence today. Agarwood is sometimes called Gaharu. The essential oil is derived from the heartwood of the agarwood tree. There are a number of popular species but typically aquilaria malaccensis, aquilaria agallocha or Aquilaria crassna are used to make the oil. Agarwood is native to India as well as several areas of South East Asia including Vietnam, the Philippines and Indonesia.

When the trees are healthy, agarwood has a light or pale color but when it is infected by disease, the process of infection creates a response to the attack resulting in a very dark and incredibly aromatic resin known as oleoresin. It is this rich dark resin which is so highly prized and from which agarwood essential oil is extracted.

In the wild, the production of this resin can take many years and like a good wine, the older the resin-the more prized it becomes. Because of its huge cost and extreme rarity in

the wild, the trees are now cultivated and the resin is actually created by artificial infection and its essential oil extracted by water distillation.

3.3.4 wood substitution

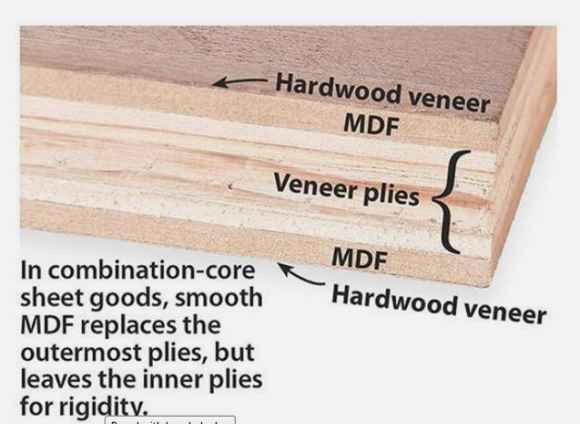
COMMON WOOD SUBSTITUTE For various reasons, many common con- struction materials are used as wood or plywood substitutes. Some are significantly less expensive than plywood; others are more suitable because of their decorative appearance and weather- resistant qualities.

Particleboard

Particleboard, commonly referred to as chip- board or flakeboard, is produced by mixing a resin-bonding agent with wood particles and bonding them together by means of heat and pressure. The use of particleboard is limited to nonstructural use because of its low strength qualities. The most common size sheets are 4 ft by 8 ft and vary from 1/4 in. to 1 1/2 in. Thick

Hardboard

Hardboard is made of compressed wood fibers subjected to heat and heavy pressure. The finish may be obtained in a plain, smooth surface or in any number of glossy finishes, some of which imitate tile or stone. Its strength is about equal in all directions, and it can be bent into various shapes. Hardboard is available in thicknesses from 1/8 in. to 3/8 in. The most common size sheets are 4 ft by 8 ft.



Fiberboard

Fiberboard is made of wood or vegetable fiber that has been compressed to form sheets or boards. They are comparatively soft and provide good insulation and sound-absorbing qualities. Fiberboard is available in sizes from 1/2 in. to 1 in. thick, 2 ft to 4 ft wide, and 8 ft to 12 ft long

Gypsum Wallboard

Gypsum wallboard is composed of gypsum between two layers of heavy paper. Some types have unfinished surfaces, while others have finishes that represent wood grain or tile. The most common thickness is 1/2 in. Its width is usually 4 ft, and its length varies from 4 to 14 ft. Another type of gypsum wallboard has depressed or tapered edges. The joints are filled with special cement and are then taped so that the joints do not show. They can then be painted.

Eco-sensitive: Bamboo

Bamboo is often considered a wood, but this grass is really a wood alternative. It has been called the world's most useful plant (though hemp advocates might argue otherwise). Bamboo is fast-growing but at least as strong as some slow-growth woods
Bamboo is making its way into all types of applications, from flooring and kitchen countertops to sheet goods and decorative banding.
As the even-toned, knot-free looks of bamboo become more and more popular, an increasing number of products and materials made out of this versatile and affordable plant.

Advantage of wood substitute

1.Environmental benefits: Utilization of industrial waste, avoid deforestation, reduction of environmental polution
2. stroger than wood
3. Weather resistance , durable
4. Corrosion-resistant
5. Termite,rot fungus ,rodent - resistant
6. fire retardent, self- extinguising nature
7. Cost-effective than Teak wood , PC product maintance free
8. Use in veriety of applications:doors, ceilings, flooring, partition, furniture.

Bamboo products

1.Bamboo pannels present significant advabtages over wooden boardsowing to their strength, rigitity and flexibility.

2. Bamboo flooring is a high value product with large dimestic and internartional market.

3. Bamboo sticks for Blinds and Incence sticks.

4.Bamboo furniture: ASa category it includes traditional productsmade of round and split bamboos

Bamboo flooring

Bamboo furniture

Bamboo house

Plastic wood

Another growing segment of the deck market is basically the plastic — recycled or not — of composites without any wood fibers. Like composite decking, plastic wood requires no maintenance. Of course, it's hard to make plastic look exactly like wood, so it's not a perfect aesthetic substitute. However, in many other ways, composites and plastic wood are good hardwood alternatives.

Recycled plastic

1.In adition to being made from recycled content HDPE plastic lumberis a truely recyclablematerial that can be usedover and over again.

2.Its resistance to decay and ability to with stand severe weather ensures a life time of use without sacrificing the look of the porducts.

3.Since plastic is succeptible to expansionand contraction from variable temperature, HDPE solutions are mixed to it during manufaturing to increase durability and to decrease expansion and contraction,

4. Since minarals are not organic material recycled plastic lumberremains impervious to rot,mold , mildew,insects and other decay.

Straw

Look closely at plywood. The fibers look a lot like straw, so it's no stretch to imagine particleboard from a variety of straw varieties, including wheat, oat and flax straw. All these are available and useful alternatives to traditional pressed wood products.

3.4 Cellulose and Paper industry

3.4.1 Demand and supply situation of raw material for papper and pulp industry

Estimation of PCF (Product Carbon Footprint) for energy-intensive industry such as pulp and paper is very much necessary particularly for a developing economy such as India. At present in India, there are in total 759 pulp and paper mills with an installed capacity of 12.7 million tons producing around 10.11 million tons/ annum of paper/paper board and newsprint out of the total world production of around 402 million tons (Kulkarni, 2013). The Indian paper industry structure consists of small-, medium-, and largesized paper mills having production capacities ranging from 10 to 1150 tons per day (Kulkarni, 2013).

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Paper mills in India continue to face challenges with waste-paper-based raw materials. Of the 4.5 million tons of waste paper requirement for recycling, the indigenous waste paper available for recycling is 2.0 million and 2.5 million tons depending on import (Kulkarni, 2013). This occurs because agro-based industries are closing down as a result of pollution-related problems and waste paper quality, thereby putting pressure on the paper industry.

3.4.2 Manufature of paper

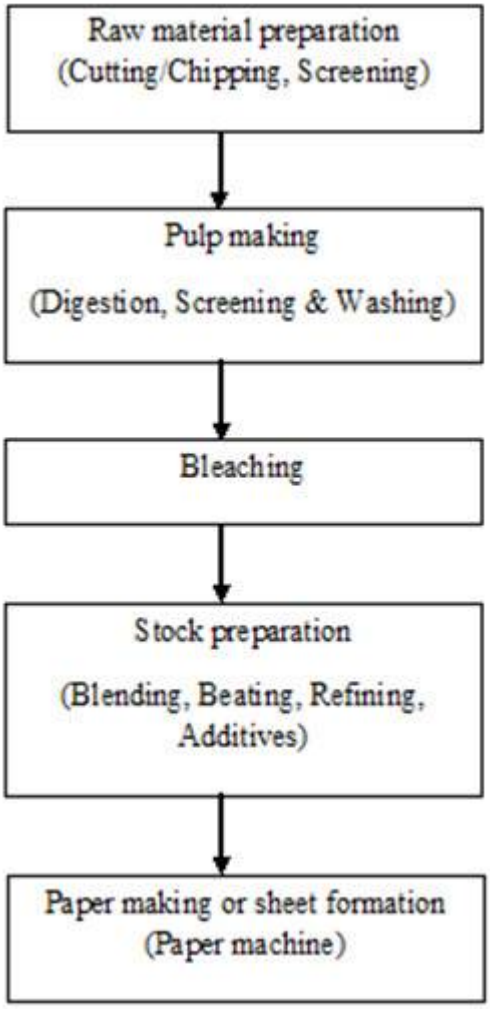
Raw material preparation

Natural fibre based raw materials are received and cut or chipped into small pieces of size 0.5-1" and then screened for further processing.

Pulp making

Pulping generally refers to various industrial processes used to convert raw plant materials or recycled paper into a fibrous raw material known as pulp, which is used primarily to make paper or paperboard products. Predominantly, pulp making is done either by mechanical or chemical means. In mechanical process, the raw material is reduced to small particles by rubbing against huge grindstones revolving at high speeds. In the chemical process, the cellulose fibers of the raw material are separated from the non-cellulose components by chemical action.

Paper manufacturing process flow chart



Three primary chemical processes are in use, viz., Kraft or sulphate (alkaline), sulphite (acidic) and Neutral Sulphite Semi Chemical (NSSC). All large Pulp & Paper mills in India use the Kraft/sulphate chemical process for pulping. In this process, the raw material is cut to 0.5-1" size. Then the raw materials are fed into digesters, reacted with white liquor (80:20 NaOH and NaS) and steamed for about two to three hours at high temperature and pressure (162 - 168^{o}C and 7-8 kg/cm^{2}). Digesters may be batch or continuous type, the latter offering advantages such as increased throughput, reduced labour and better energy utilization. Continuous digesters are also very useful in agro fiber pulping. The pulp is then washed to make the pulp free from soluble impurities and removal of black liquor through usual 3 or 4 stages of counter current washing using rotary drum filters. The washed pulp is then sent for bleaching to increase the brightness of the pulp and the dilute black liquor is sent to evaporators.

Bleaching Process

Pulp when it comes from digester contains residual coloring matter. This unbleached pulp may be used for making heavy wrapping paper or bags. However, paper to be used for printing, writing or paper which is to be dyed must first be bleached. The main object in bleaching is to remove residual lignin from the pulp fibers as well as to destroy or remove

remaining colouring matter. Chemical pulps are bleached through the use of alternating treatments of oxidizing agents and alkali solutions. Mechanical pulps are treated with hydrogen peroxide or sodium hydrosulfite to reduce the light absorption of the lignin rather than remove it. Nowadays various bleaching agents are used to bleach the pulp like chlorine, chlorine dioxide, hydrogen peroxide, oxygen and calcium hypo chlorite.

Stock preparation

Stock preparation is undertaken to give the pulp various desired qualities through refining. It is mostly accomplished in either double disk or conical refiners. A more vigorous and special type of refiner known as Jordan is used in mechanical pulp preparation method in which a conical plug rotates in conical shell. The stock then undergoes addition of sizing, filling and coloring agents. A final screening & centri-cleaning is carried out prior to paper making for removing the contaminants as they may lead to defects in paper.

Sheet formation & water removal

The feed to the paper machine consists of combination of refined pulp together with additives such as fillers and wet end chemicals having requisite stock consistency. Either fourdrinier or cylindrical mould machines form the above feed into a sheet. Mills producing cultural and newsprint paper use high-speed fourdrinier and twin wire sheet formers. Mills producing packaging paper & board mainly use cylindrical mould machines. At wet end of paper machine, water is first removed by gravity then by suction and then by pressing the sheet and lastly by drying by steam heated cylinders.

3.4.3 Manufacture of rayon

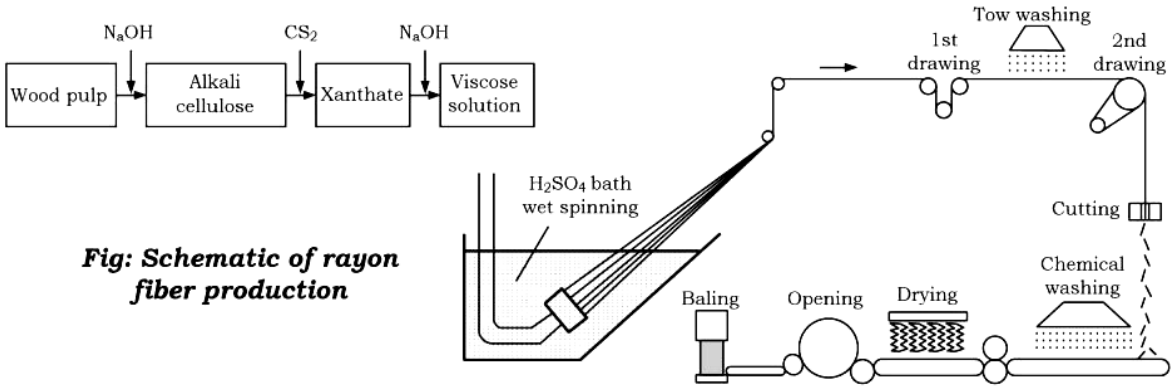


Fig: Schematic of rayon fiber production

Viscose rayon, a man-made fiber composed of 100% regenerated cellulose, was discovered in 1891, and the first commercial production was undertaken in 1905 by Courtaulds. It is made from cotton linters or wood pulp, usually obtained from spruce and pine trees. Initially, viscose was called “artificial silk” and later named as rayon because of its brightness and similarities in structure to cotton (rayon is a combination of sunray and cotton)

Flow chart of viscose

1. Wood Pulp
2. Steeping & Pressing
3. Shredding
4. Ageing
5. Ripening
6. Dissolving with caustic soda
7. Xanthation with carbon di-sulphide
8. Filtration
9. Extrusion & Stretching
10. Cutting of fiber
11. Wet processing drying packing
12. Viscose fibers

Steps of Viscose Manufacturing Process

1. **Preparation of wood pulp**

Wood chips treated with calcium bic-sulphide, and the treated chips then cooked with steam under the pressure.

2. **Steeping**

Cellulose pulp is immersed in 17-20% aqueous sodium hydroxide (NaOH) at a temperature in the range of 18 to 25°C in order to swell the cellulose fibers and to convert cellulose to alkali cellulose. (C6H10O5)n + nNaOH — (C6H9O4- ONa)n + nH2O

3. **Shredding**

The pressed alkali cellulose is shredded mechanically to yield finely divided, fluffy particles called “crumbs”. This step provides increased surface area of the alkali cellulose, thereby increasing its ability to react in the steps that follow.

4. **Ageing**

The alkali cellulose is aged under controlled conditions of time and temperature (between 18 and 30° C) in order to depolymerize the cellulose to the desired degree of polymerization. In this step the average molecular weight of the original pulp is reduced by a factor of two to three. Reduction of the cellulose is done to get a viscose solution of right viscosity and cellulose concentration.

5. **Xanthation**

In this step the aged alkali cellulose crumbs are placed in vats and are allowed to react with carbon disulphide under controlled temperature (20 to 30°C) to form cellulose xanthate. (C6H9O4-ONa)n + nCS2 — (C6H9O4O-SC-SNa)n

6. **Dissolving**

The yellow crumbs of cellulose xanthate is dissolved in aqueous caustic solution. Because the cellulose xanthate solution (or more accurately, suspension) has a very high viscosity, it has been termed “viscose”.

7. **Ripening**

The viscose is allowed to stand for a period of time to “ripen”. Two important process occur during ripening: Redistribution and loss of xanthate groups. The reversible xanthation reaction allows some of the xanthate groups to revert to cellulosic hydroxyls and free CS2. This free CS2 can then escape or react

with other hydroxyl on other portions of the cellulose chain. In this way, the ordered, or crystalline, regions are gradually broken down and more complete solution is achieved. The CS2 that is lost reduces the solubility of the cellulose and facilitates regeneration of the cellulose after it is formed into a filament.

$(C_6H_9O_4O\text{-}SC\text{-}SNa)_n + nH_2O \longrightarrow (C_6H_{10}O_5)_n + nCS_2 + nNaOH$

8. **Filtering**

The viscose is filtered to remove undissolved materials that might disrupt the spinning process or cause defects in the rayon filament.

9. **Degassing**

Bubbles of air entrapped in the viscose must be removed prior to extrusion or they would cause voids or weak spots in the fine rayon filaments.

10. **Spinning – (Wet Spinning) Production of Viscose Rayon Filament**

The viscose solution is metered through a spinneret into a spin bath containing sulphuric acid (necessary to acidify the sodium cellulose xanthate), sodium sulphate (necessary to impart a high salt content to the bath which is useful in rapid coagulation of viscose) and zinc sulphate (exchange with sodium xanthate to form zinc xanthate, to cross link the cellulose molecules). Once the cellulose xanthate is neutralized and acidified, rapid coagulation of the rayon filaments occurs which is followed by simultaneous stretching and decomposition of cellulose xanthate to regenerated cellulose.

Spinning Bath Composition of Viscose Fiber

1. Na_2So_4 : 15-20%
2. H_2So_4 : 7-10%
3. $ZnSo_4$: 1-5%
4. Glucose : 1-2%
5. Spinning Bath Temperature: 40-55*C

Drawing

The rayon filaments are stretched while the cellulose chains are still relatively mobile.

4. SAW MILLING

4.1 Types of saws , saw mill mechinery.

Saws have been in use for thousands of years, branching out to fill specific niches as the times, technology, and materials required. Today's "complete" tool collection will include a variety of saws, from coping saws to hacksaws to any of a number of specialized table saws, and sometimes includes more than one saw of a given type.

There are many specialized cutting tools as well, but they are not commonly used outside of trades they were developed for.

Types of saws which are commenly in use are fallows .

- **Hand Saws**. Back Saw. Bow Saw. Coping Saw. Crosscut Saw. Fret Saw. Hacksaw. Japanese Saw. Keyhole Saw. Pole Saw. ...
- **Power Saws**. Band Saw (Stationary) Band Saw (Portable) Chain Saw. Chop Saw. Circular Saw. Compound Miter Saw. Flooring Saw. Jigsaw. Miter Saw.

Hand Saws

Hand saws have evolved to fill many niches and cutting styles. Some saws are general purpose tools, such as the traditional hand saw, while others were designed for specific applications, such as the keyhole saw.

1. Back Saw

A back saw is a relatively short saw with a narrow blade that is reinforced along the upper edge, giving it the name. Back saws are commonly used with miter boxes and in other applications which require a consistently fine, straight cut. Back saws may also be called miter saws or tenon saws, depending on saw design, intended use, and region.

2. Bow Saw

Another type of crosscut saw, the bow saw is more at home outdoors than inside. It uses a relatively long blade with numerous crosscut teeth designed to remove material while pushing and pulling. Bow saws are used for trimming trees, pruning, and cutting logs, but may be used for other rough cuts as well.

3. Coping Saw

With a thin, narrow blade, the coping saw is ideal for trim work, scrolling, and any other cutting which requires precision and intricate cuts. Coping saws can be used to cut a wide variety of materials, and can be found in the toolkits of everyone from carpenters and plumbers to toy and furniture makers.

4. Crosscut Saw

Designed specifically for rough cutting wood, a crosscut saw has a comparatively thick blade, with large, beveled teeth. Traditional 2-man crosscut saws (aka felling saws) have a handle on each end and are meant to be used by two people to cut across (perpendicular) the grain of timber.

The more common 1-man crosscut saw is great for rough cutting lumber, trimming limbs or branches, and makes an excellent saw for camping or at the job site.

5. Fret Saw

Most closely resembling a coping saw, the fret saw has a long, thin blade for making intricate cuts. The fret saw has a longer, larger frame that allows cutting farther from the outer edges, but the blade cannot be rotated, which results in more tedious and difficult cutting positions when performing intricate scrollwork.

6. Hacksaw

Perfect for cutting pipes and tubing, the hacksaw is one of the most common saw types. They are lightweight and versatile, able to cut through wood, metal, plastic and other materials using material-specific cutting blades with a tooth count ranging from about 18 to 32 per inch.

6. Japanese Saw

Built with a single handle and a protruding strong, thin cutting blade, this type of saw is more precise than a back saw and has the advantage of being able to reach places where other saws cannot reach.

These saws are available in three types (dozuki, ryoba, and kataba), and can be used to cut hard and soft woods with equal precision.

7. Keyhole Saw

Best described as a round handle with a single blade protruding from the top of the handle, a keyhole saw is used to rough cut circles or patterns.

Keyhole saws can be indispensable for drywall, especially when a small section needs to be removed and/or replaced, or where the interior of the wall prevents the use of powered tools.

8. Pole Saw

Also referred to as a pole runner, this saw has an extendable pole, giving it a reach of 7 to 16 feet (or more), depending on the model. The

cutting end is a six to eight inch pruning blade designed for pruning trees.
Many models of these saws are now powered, with a chainsaw-like end and using gas or electricity as a fuel source.

9. Pruning Saw

Pruning saws most often have a 13-15″ curved blade, protruding from a single "pistol grip" style handle. The blade is wide and has coarse teeth that are able to cut in both directions for faster material removal.
Pruning saws are more commonly found in a homeowner's toolkit, but they are also widely used by tree surgeons, lawn services, and landscapers.

10. Rip Cut Saw

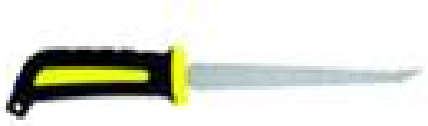
Often referred to simply as a "hand saw," the rip cut saw is a must-have for framing. It has relatively few teeth per inch, but each tooth is a sharpened point designed to remove wood. Anyone who works with wood will have one or more rip cut saws, usually of varying lengths.

11. Veneer Saw

Another highly specialized saw, the veneer saw is designed with a short double-edged blade that has about 13 teeth per inch. This saw is specifically used for precision veneer work, and the short blade prevents it being readily adapted to most other cutting tasks.

12. Wallboard Saw

Looking very similar to a keyhole saw, the wallboard saw generally has a shorter, wider blade and fewer teeth per inch and often comes in a double-edge variety. It is designed for puncturing through paneling or drywall, and is often used to create starter holes for powered tools.



Power Saws

Rather than simply duplicating various handheld saws, powered saws have evolved to fill niches of their own. For example, a radial arm saw expands on the capabilities of a miter saw and circular saw, but does not directly duplicate either.

Powered saws come in three primary categories: Continuous Band, Reciprocating Blade, and Circular Blade.

1. Band Saw (Stationary)

This tall, floor-standing saw uses large pulleys above and below the cutting table to move a continuous band with fine teeth to cut through most materials.

Band saws are perfect for intricate cutting of curves into wood, as well as cutting tubes, piping, and PVC, but are limited to a depth of only a few inches.

Resawing (cutting boards so they are thinner) is possible with a band saw by standing the board on its edge and carefully ripping it using a fence. Patience is definitely required for this task.

Horizontal

Vertical

2, Band Saw (Portable)

A small portable version of the stationary unit, it can accomplish most of the same jobs as its big brother with the portability to be able to take to a jobsite or someone else's garage.

it takes more effort to make straight cuts, but it can be an invaluable tool especially for plumbers, welders, and metalworkers.

3. Chain Saw

As the name implies, a chainsaw uses a linked chain with numerous specially designed ripping teeth. While chainsaws are uniquely designed, they fall into the category of band saws.

4. Chop Saw

One of the largest portable versions of circular saws, the chop saw is manufactured in both metal and masonry cutting versions. The concrete cutting saw often includes a connection for a water line to reduce dust while cutting.

Both types of chop saws use toothless blades manufactured with special abrasives designed for the materials to be cut. Chop saws are also known as cut-off saws, concrete saws, and abrasive saws.

5. Circular Saw

Sometimes referred to as a buzz saw or by the popular brand name of Skilsaw, circular saws use a toothed blade, typically between 7-¼ and 9 inches in diameter.

They are the most common type of powered saw, and accept blades that cut all types of wood, metal, plastic, masonry, and more.

6. Flooring Saw

As the name implies, a flooring saw is a portable unit intended to re-saw flooring (hardwood, engineered, bamboo, or laminate) to fit. It's a fairly specialized tool that in essence replaces a table saw, miter saw, and other accessories you may need to cut flooring.

The portability factor is its biggest advantage as you won't have to spend a lot of time moving materials from garage to room and vice versa when putting in flooring.

7. Miter Saw

One of the few saws designed to expressly mimic a hand saw, the miter saw is ideal for use in trim or other jobs involving precise measurements and angle cuts.

7. Radial Arm Saw

By placing the motor and blade on an arm that extends over the cutting table, the radial arm saw allows you to make identical compound cuts, miter cuts, and more. Depending on the manufacturer, radial arm saw blades may be interchangeable with circular saw blades, but verify the recommended speed of spin, as some radial *saws turn very fast.*

***8*. Rotary Saw**

Rotary saws (or rotary tools) have a fixed blade and a small screwdriver-type handle. They are used for everything from crafts to construction, and are ideal for cutting into a wall for access or repairs.

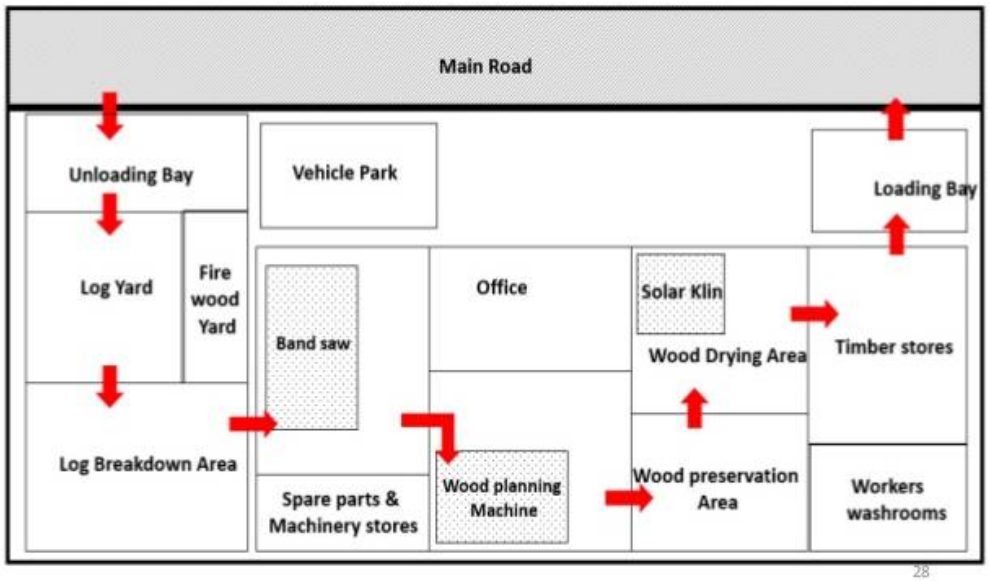
Like the keyhole saw, a rotary saw is essential for drywall, panelling, and a myriad of other small cutting tasks.

9. Table Saw

Table saw blades tend to be a little larger than for a circular saw, and consist of a high speed motor mounted beneath a flat table. To adjust the the depth of cut, the blades rises out of the table bed.

Table saws are great for making numerous rip cuts or preparing a large number of identical sized pieces. These saws accept metal and masonry blades, but take care that the blade design matches the motor rpm.

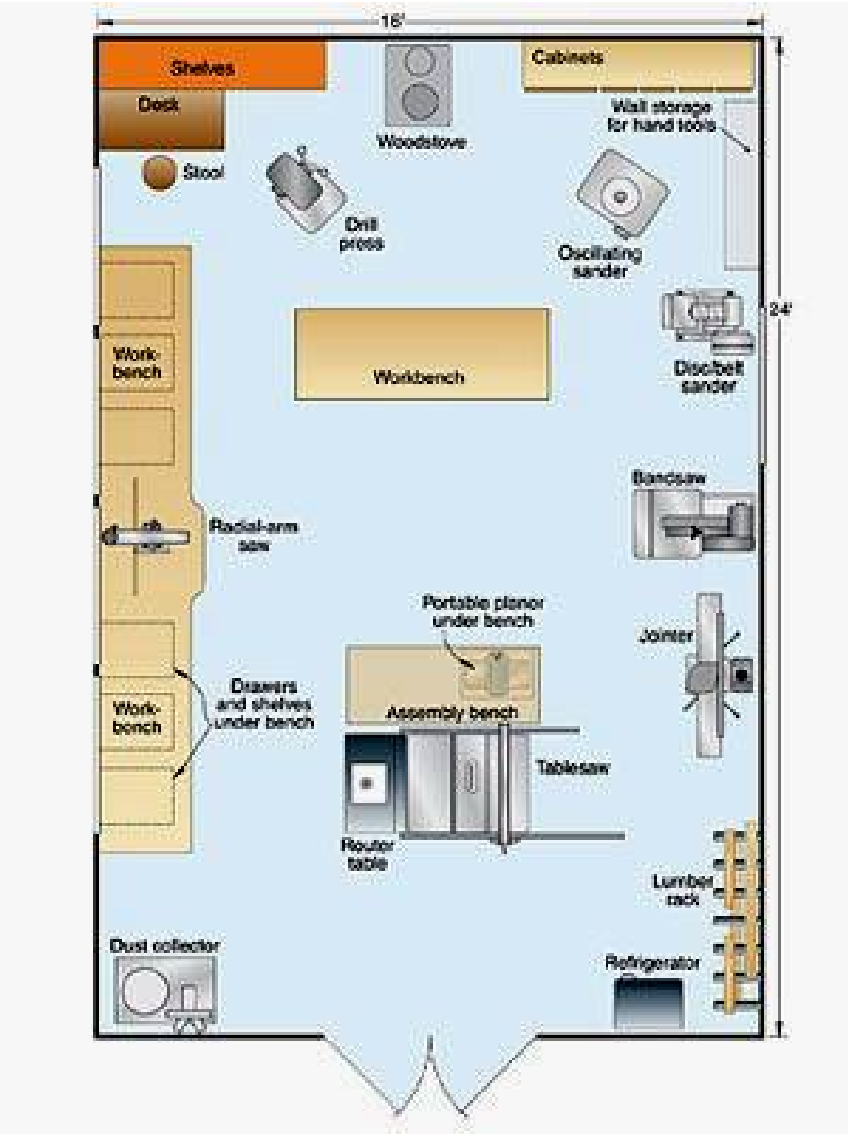
4.2 Design and lay out of saw mills and wood work shop.



Saw mill premises

Saw mill lay out will depend on how many sorts are being carried out, what size of lumber are to be sawn, power sources , amount of labour input, Extent of land available etc.It can be started with basic concept and move on from there. Stable source of logs and and fairly stable lumber market should be ensured.
A full fledged lay out concept is shown above.

Lay out for wood work shop



Wood work shop lay out tips.

1. Think about work flow
2. Group tools sensibly
3. Store tools near work bench
4. Put work bench near window
5. Store wood near the entrance
6. Put Miter saw near lumber rack
7. Locate the assembly table centrally

8. Keep the clamps near the assembly table.
9. Locate the table saw centrally
10. Finish near a window

4.3 wood working

Woos is used for construction of various buildings at various levels. Wood is particularly used in the construction industry, for load carrying structures such as trusses , arches , girders, beams and rafters, frame work , and for walling elements such as wall panels, partitions etc. Wood is found in the construction of window units, door, flooring, furniture and so on.

The economic use and proper working of wood are the most efficient way of utilizing wood.

In order to learn basic wood working process information on the use of hand and power tools employed in wood working , elements of joinery works, basic process of fabrication are dealt with .

Factors in choosing materials

There are many factors to consider when deciding what type of wood to use for a project. One of the most important is the workability of the wood: the way in which it responds when worked by hand or tools, the quality of the grain, and how it responds to adhesives and finishes. When the workability of wood is high, it offers a lower resistance when cutting and has a diminished blunting effect on tools. Highly workable wood is easier to manipulate into desired forms. If the wood grain is straight and even, it will be much easier to create strong and durable glued joints. Additionally, it will help protect the wood from splitting when nailed or screwed.[1] Coarse grains require a lengthy process of filing and rubbing down the grain to produce a smooth result.

Another important factor to be considered is the durability of the wood, especially in regards to moisture. If the finished project will be exposed to moisture (e.g. outdoor projects) or high humidity or condensation (e.g. in kitchens or bathrooms), then the wood needs to be especially durable in order to prevent rot. Because of their oily qualities, many tropical hardwoods such as teak and mahogany are popular for such applications.

Woods used for carving

While many woods can be used for carving, there are some clear favorites, including Aspen, Basswood, Butternut, Black Walnut, and Oak.Because it has almost no grain and is notably soft, Basswood is particularly popular with beginner carvers. It is used in many lower-cost instruments like guitars and electric basses. Aspen is similarly soft, although slightly harder, and readily available and inexpensive. Butternut has a deeper hue than Basswood and Aspen and has a nice grain that is easy to carve, and thus friendly for beginners. It's also suitable for furniture. While more expensive that Basswood, Aspen, and Butternut, Black Walnut is a popular choice for its rich color and grain. Lastly, Oak is a strong, sturdy, and versatile wood for carving with a defined grain. It's also a popular wood for furniture making.

Tools for wood working

Common Tools

There are a variety of tools that can be used for woodworking. Each area of woodworking requires a different variation of tools. Power tools and hand tools are both used for woodworking. Many modern woodworkers choose to use power tools in their trade for the added ease and to save time. However, many choose to still use only hand tools for several reasons such as the experience and the added character to the work. While some choose to use only hand tools simply for their own enjoyment.

Hand Tools

Hand tools are classified as tools that receive power only from the hands that are holding them. The more common modern hand tools are:

Clamps-

Clamps are used to hold your workpiece while either being cut, drilled, or glued. Clamps vary in all shapes and sizes from small c-clamps to very large bar or strap clamps.

Chisels-

Chisels are tools with a long blade, a cutting edge, and a handle. Used for cutting and shaping wood or other materials.

Claw Hammer-

The claw hammer is the hammer of choice for anyone in woodworking because of the multi-use claw for pilling nails or prying against joints.

Square-

The square is used to measure perfect angles on any workpiece.There are many different types of squares available. The most common is a speed square.

Tape Measure-

A tape measure is a retractable ruler that has measurement increments as small as 1/32". This is the most convenient form of measuring tool because of its small size and it is easy to use.

Plane

It is used for finish planing and also for joining for different parts

Marker

It is used for marking before joints are chiseled

Mallet.

A mallet is a wooden hammer. If you're going to use a chisel you have to use it with a mallet. Using a regular hammer is a big no. Wooden projects such as furniture almost always require tapping to put things in place or to make them stronger. Using a regular hammer will most likely cause damage. Mallets are your only option. Get them is a few different sizes so they suit all your projects big and small.

Power Tools

Power tools are tools that are powered by an external energy such as a battery, motor, or a power cable connected to a wall outlet. The more common power tools are:

Drill-

A drill is a tool primarily used for making round holes or driving fasteners. It is fitted with a bit, either a drill or driver, depending on application, secured by a chuck. Some powered drills also include a hammer function. Drills vary widely in speed, power, and size.

.

Circular saw

A circular saw is a power-saw using a toothed or abrasive disc or blade to cut different materials using a rotary motion spinning around an arbor. A hole saw and ring saw also use a rotary motion but are different from a circular saw. Circular saws may also be loosely used for the blade itself.

Sander-

A Palm Sander is a small powered sander that uses either a vibration or orbital motion to move a piece of sand paper upon the workpiece making very fine modifications in smoothing your product.

Miter Saw-

A Compound Miter Saw, also known as a chop saw is a stationary saw used for making precise cuts across the grain path of a board. These cuts can be at any chosen angle that the particular saw is capable of.

Table Saw-

A table saw is a woodworking tool, consisting of a circular saw blade, mounted on an arbor, that is driven by an electric motor. The blade protrudes through the top of a table, which provides support for the material, usually wood, being cut

.

Planer-

Thickness Planers are used to smooth the surface of a board along with making them the exact thickness across the entire board. Hand Planers are used only for surfacing a board or workpiece while removing more material than a sander.

Band Saw-

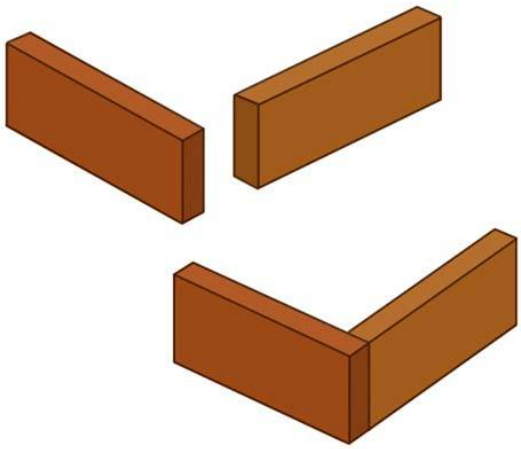
The Vertical Band Saw uses a long belt shaped blade (Band) in order to make cuts such as sharp round corners or even safely sawing through round material.

Bench-top Mortiser. Mortise and tenon joints take time and work if make them by hand. This machine makes them super quickly and effortlessly.

Basic Woodworking Joints

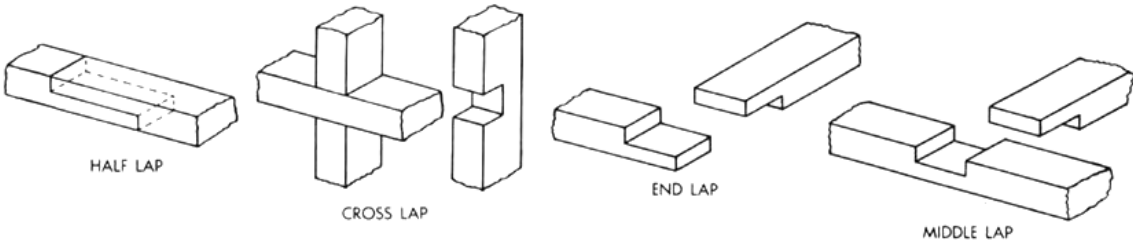
1. Butt Joint

The Butt Joint is an easy woodworking joint. It joins two pieces of wood by merely butting them together. The butt joint is the simplest joint to make. It is also the weakest wood joint unless you use some form of reinforcement. It depends upon glue alone to hold it together. Because the orientations of the pieces, you have an end grain to long grain gluing surface. The resulting wood joint is inherently weak. Glue does not provide much lateral strength. You can break this woodworking joint with your bare hands.



2. Lap Wood Joint

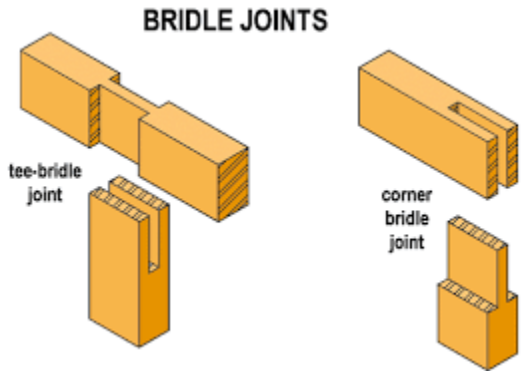
A half lap joint is one of the frequently used woodworking joints. In a half lap joint, you remove material from each piece so that the resulting joint is the thickness of the thickest piece. Most frequently in half lap joints, the pieces are of the same thickness. You remove half the thickness of each.This joint is good for making workshop storage items.

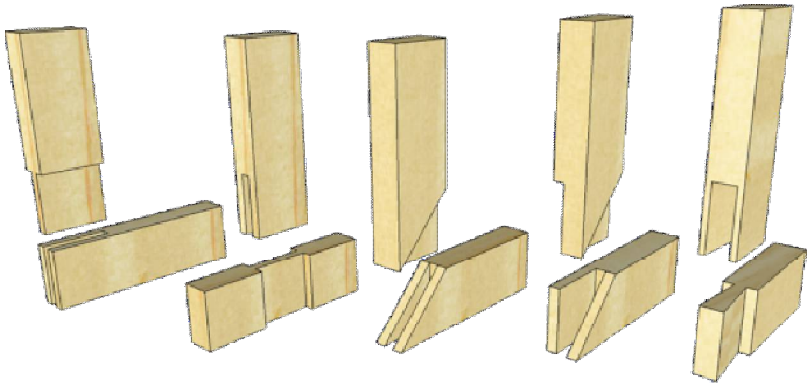


Multi lap joint

3. <u>Bridle joint</u>

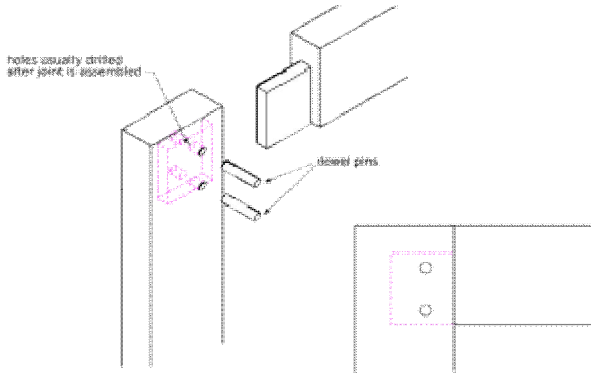
Also known as open tenon, open mortise and tenon, or tongue and fork joints, this joint is where the through mortise is open on one side and forms a fork shape. The mate has a through tenon or necked joint. Bridle joints are commonly used to join rafter tops, also used in scarf joints and sometimes sill corner joints in timber framing.





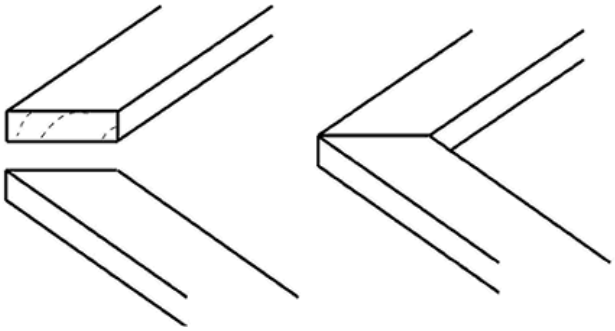
- **Dowel joint**

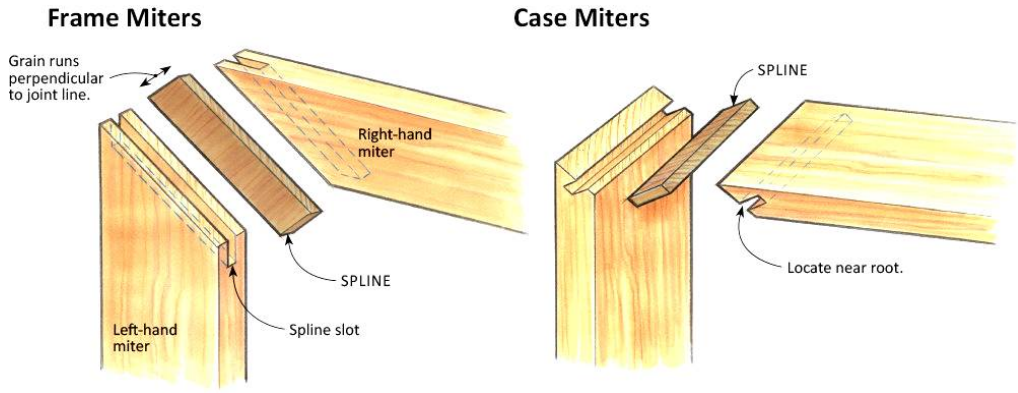
- The end of a piece of wood is butted against another piece of wood. This is reinforced with dowel pins. This joint is quick to make with production line machinery and so is a very common joint in factory-made furniture.

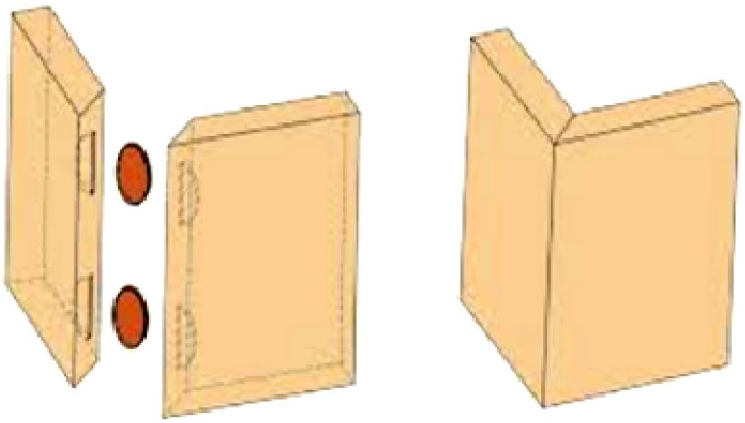


- This joint is pretty self-explanatory. As one of many variations of a butt joint, the dowel joint is one of the most popular joints. Especially when it comes to tabletops, cabinets, and chairs to name a few.
- Dowel joints give the illusion of a standard butt joint. Except without the need for countersinking screws or nails and filling in the hole. This results in a much more pleasing look to the final project!
- Unlike a mortise and tenon joint which uses larger square and rectangle shaped joints. The dowel joint uses cylindrical 'pins' (the aforementioned dowels) as a way of holding the joint together. All without being seen. These types of joints require careful planning and glue to be as strong as they can get. It need to drill two holes that line up perfectly that are half the depth of the dowel itself. Use glue in the holes to keep the dowel in nice and tight!
- **Mitre joint**

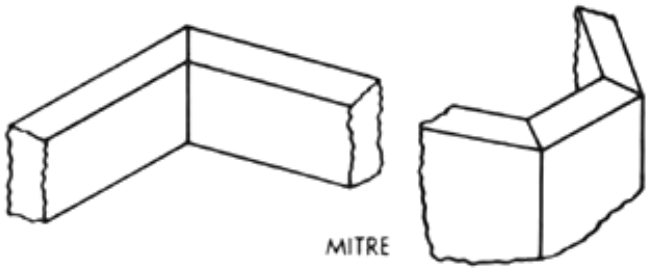
- Similar to a butt joint, but both pieces have been bevelled (usually at a 45 degree angle)







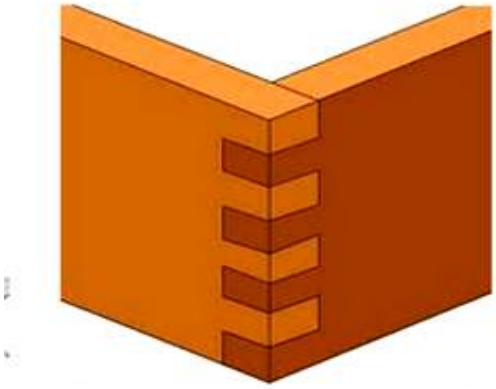
miter joint reinforced with biscuits ...



Finger Joint / Box joint

- A finger joint or box joint is one of the popular woodworking joints. It is used to join two pieces of wood at right angles to each other. It is much like a dovetail joint except that the pins are square and not angled. The joint relies on glue to hold together. It does not have the mechanical strength of a dovetail. The woodworking joint is

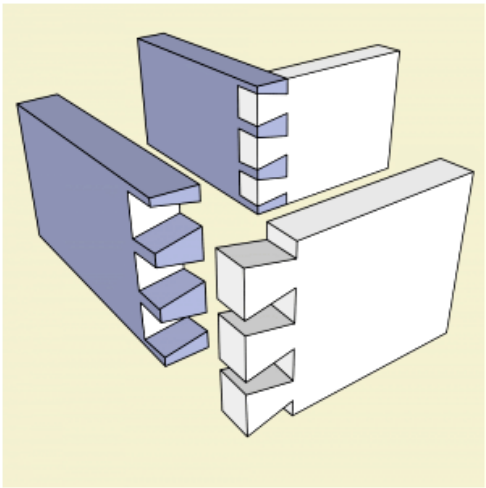
relatively [easy to make if you know how to use a table saw](#) or a wood router with a simple jig.



7. Dovetail Wood Joint

The dovetail joint, or simply dovetail, is a strong woodworking joint.It is great for tensile strength (resistance from pulling apart). You use the dovetail joint to connect the sides of a drawer to the front. A series of pins cut to extend from the end of one board interlock with a series of tails cut into the end of another board. The pins and tails have a trapezoidal shape.Once glued, the joint is permanent, and requires no mechanical fasteners. Some people use a dovetailed dado, because of the tensile strength.

Through Dovetail

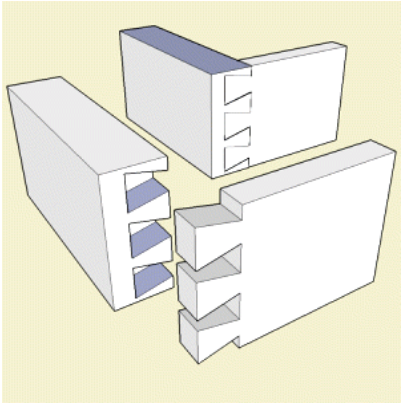


A common joint used in furniture, the Through dovetail shows the end grain of both pieces of lumber you're joining. Also known as an English Dovetail this type of joint is characterized by a trapezoidal shape or the 'tails' of the wood and has been seen in tombs of emperors, and mummies.

It's a variation of the concepts set forth by the mortise and tenon joint we discussed above.

This joint is strong with using just friction but can be next to impossible to pull apart when some glue is applied.

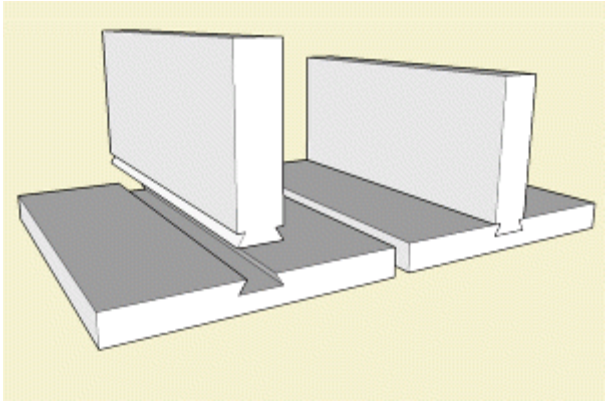
Half-Blind Dovetail



The major difference between a through dovetail and a half-blind dovetail is in the front of the joint.

This allows the wood to still hold on tightly, but keep the end grain of the side piece of wood hidden when viewed from the front. This is common when joining the front of a drawer to the sides.

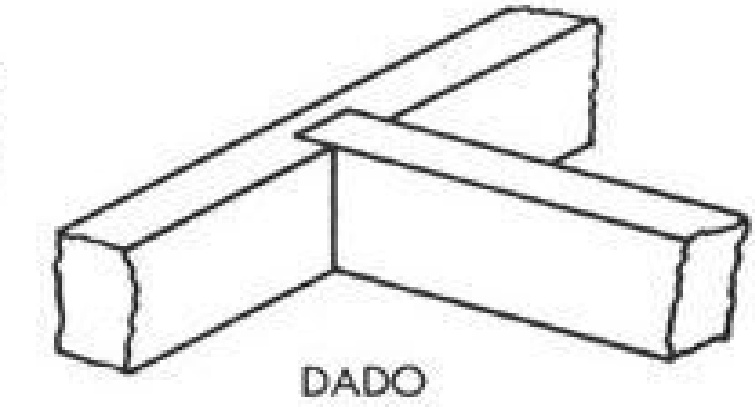
Sliding Dovetail



This type of dovetail is used for joining two pieces of lumber at a right angle.

8.<u>Dado joint</u>

Also called a *housing joint* or *trench joint*, a slot is cut across the grain in one piece for another piece to sit in; shelves on a bookshelf having slots cut into the sides of the shelf, for example.

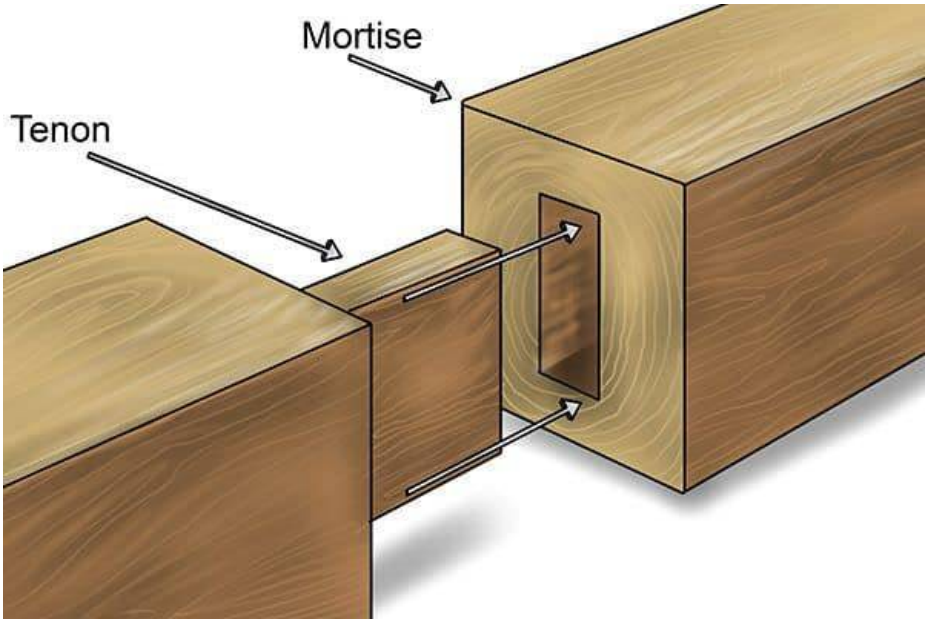


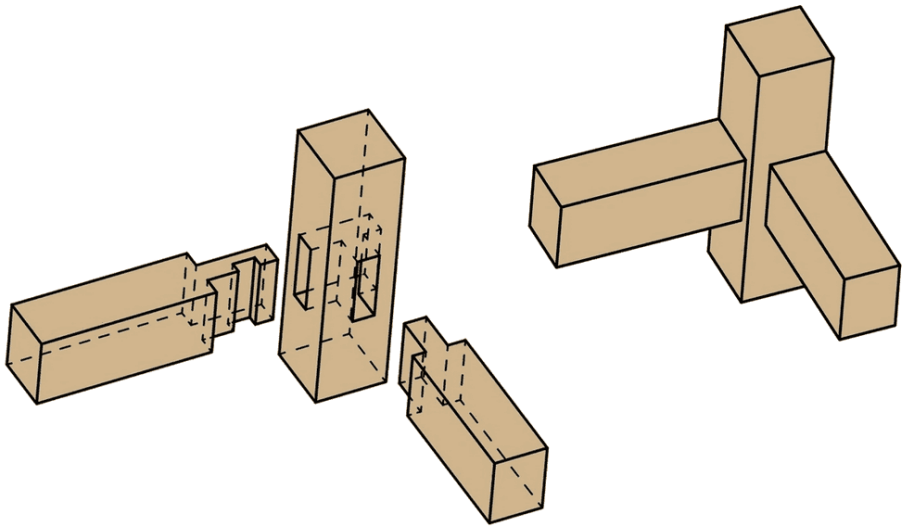
9. Tongue and Groove Woodworking Joints

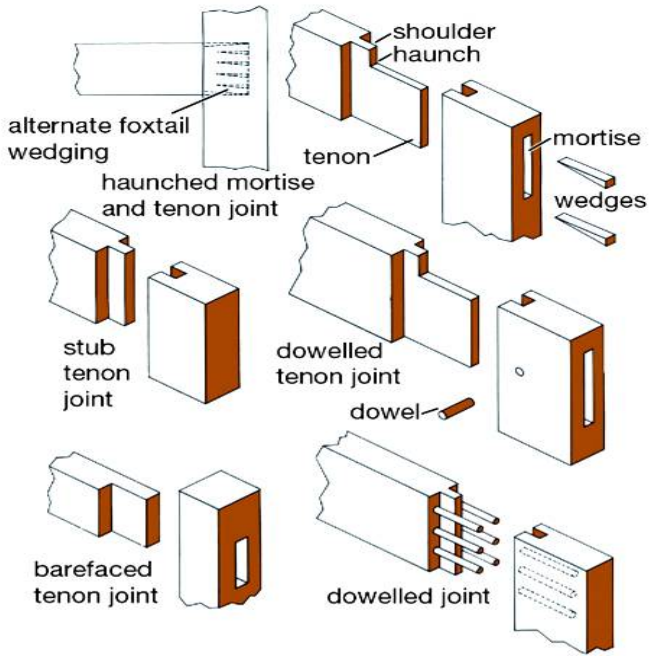
One of the more popular woodworking joints is the edge-to-edge joint, called tongue and groove. One piece has a slot (groove) cut all along one edge. The other piece has a tongue cut on the mating edge. As a result, two or more pieces fit together closely.It can be used to make wide tabletops out of solid wood. Some other uses are in wood flooring, parquetry, paneling, etc.

10. Mortise and tenon

A stub (the tenon) will fit tightly into a hole cut for it (the mortise). This is a hallmark of Mission Style furniture, and also the traditional method of jointing frame and panel members in doors, windows, and cabinets. This joint is a good strong joint to use.

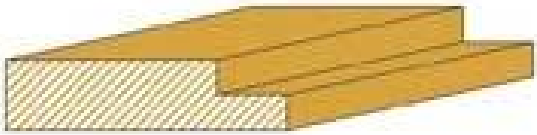


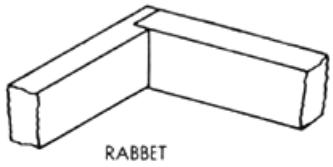




11. Rabbet Woodworking Joints

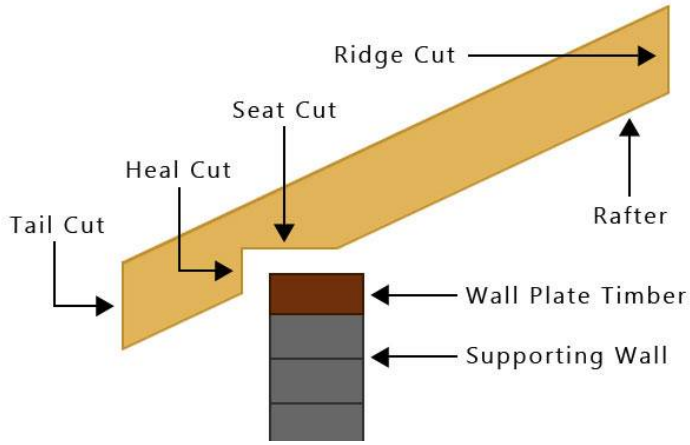
A rabbet is a recess cut into the edge of a piece of wood. When viewed in cross-section, a rabbet is two-sided and open to the end of the surface.An example of the use of a rabbet is in the back edge of a cabinet. The rabbet allows the back to fit flush with the sides. Another example is the insertion of a glass pane by using a rabbet around the edge of the frame.





12. <u>Birdsmouth joint</u>

A joint in which the two members are joined by removing material from each at the point of intersection so that they overlap.



13. Splice joint

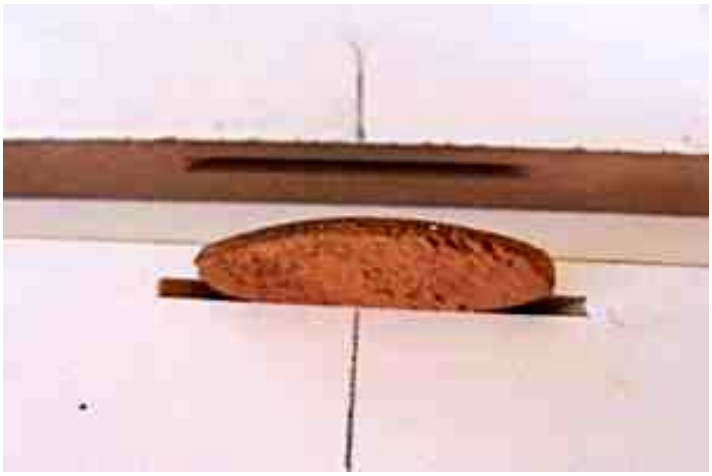
A joint used to attach two members end to end.

14. Pocket-Hole Joinery

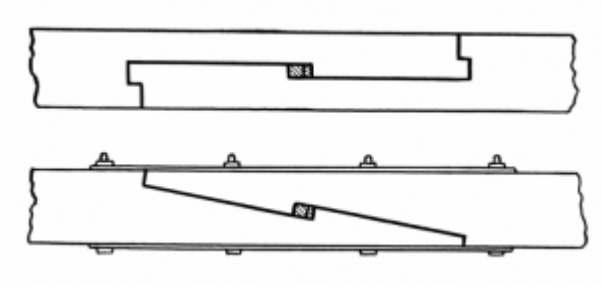
One of the more popular woodworking joints is the Pocket-Hole Joint. It is nothing more than a Butt joint with Pocket Hole Screws. The pocket holes require two drilling operations. The first is to counterbore the pocket hole itself, which takes the screw head contained by the piece.The second step is to drill a pilot hole whose centerline is the same as the pocket hole.The pilot hole allows the screw to pass through one piece and into the adjoining piece. You use two different sized drill bits for this operation. Alternatively, you may find special stepped bits to perform this operation in a single pass.

15. Biscuit Joint

A biscuit joint is nothing more than a reinforced Butt joint. The biscuit is an oval-shaped piece. Typically, a biscuit is made of dried and compressed wood, such as beech. You install it in matching mortises in both pieces of the wood joint. Most people use a biscuit joiner to make the mortises. Accuracy is not as important for the mortises. You design the biscuit joint to allow flexibility in glue-up.



16. Scarf Joint

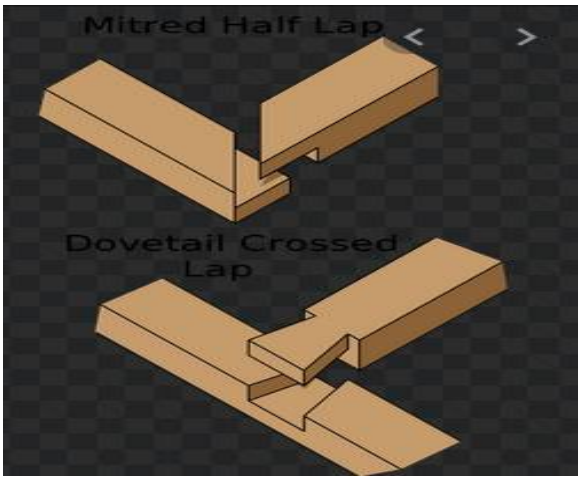


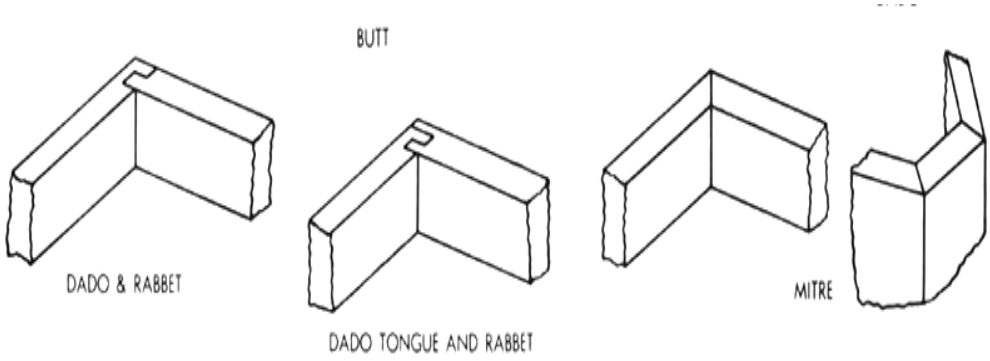
These types of joints usually are used when a piece of wood needs to be longer than the original lumber. It provides a much better continuity between wood than a typical butt joint. This is due to the long grains joining together.

Compined joints.

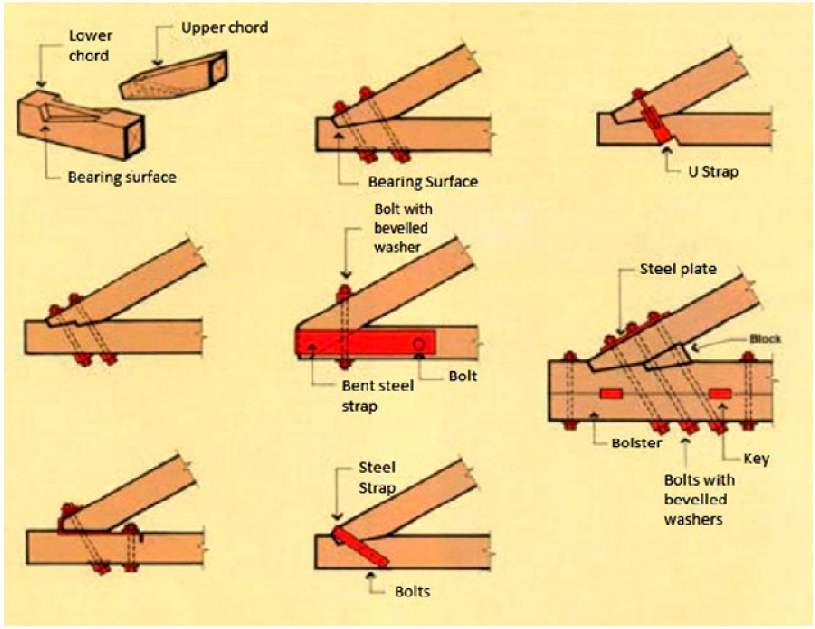
Mitred Half lap joint

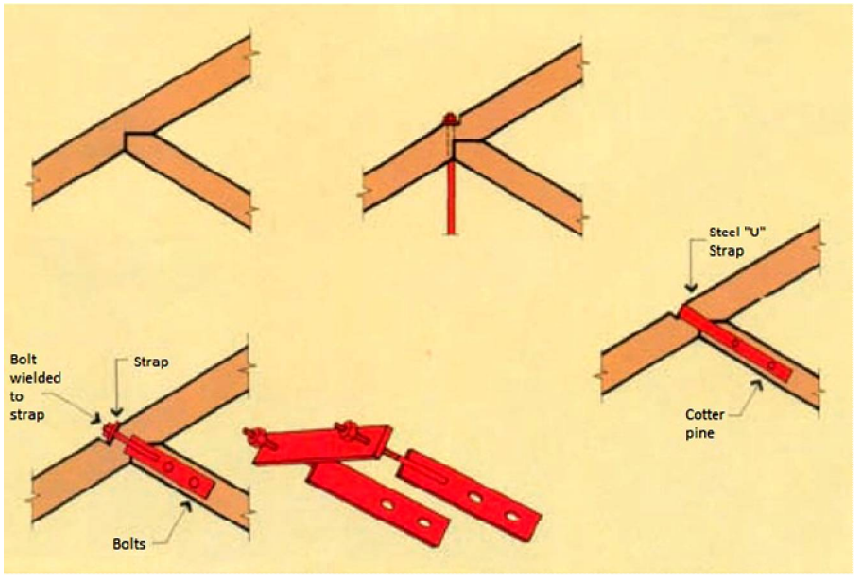
Dove tail Crossed Lap joint

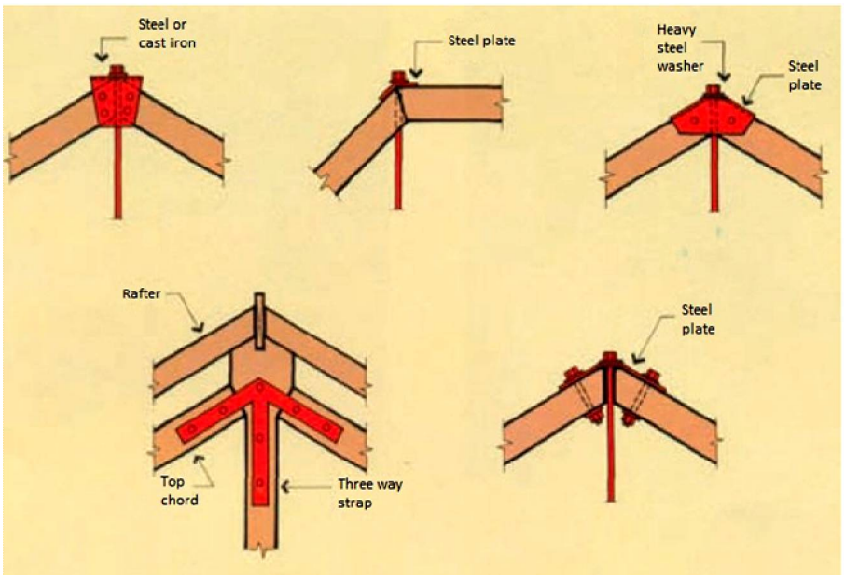


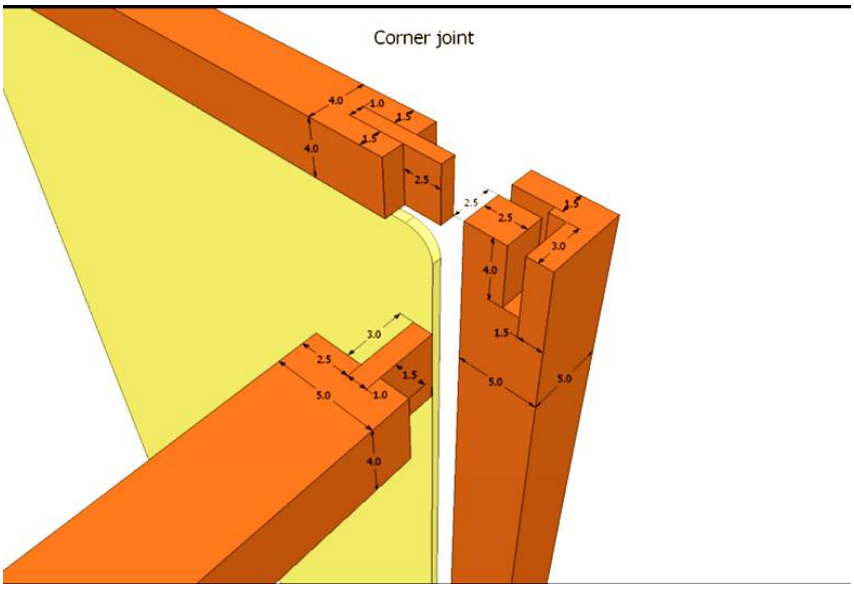


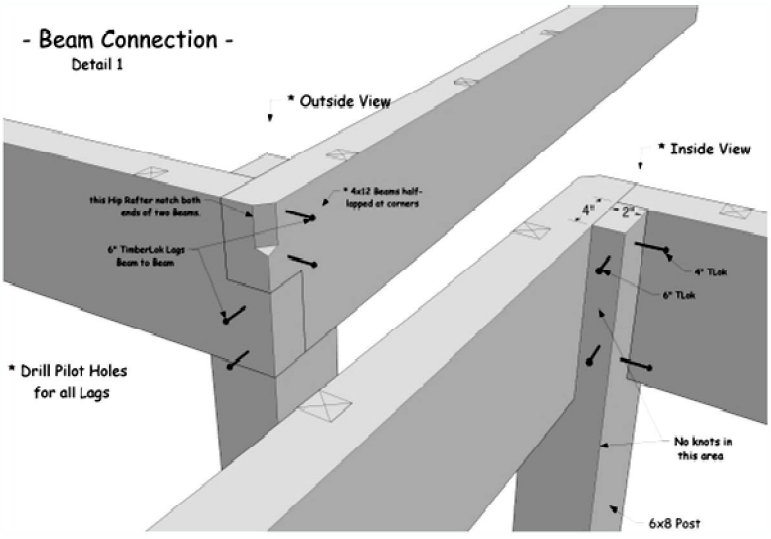
Joints for trusses











They are the foundational skills every woodworker should know.

1. Understand How **Wood** Works and Behaves. ...
2. Sharpen Saws, Planes, and Chisels. ...
3. Use a Hand Plane. ...
4. Prep Lumber With Hand Tools. ...
5. Cut a Mortise and Tenon Joint. ...
6. Cut Dovetail Joints. ...
7. Finish Your Furniture.

Wood working tips to make wood work easier and more efficient:

1 – Sanding made easier. ...

2 – Avoid drywall screws for woodworking. ...

3 – Know your wood's moisture content. ...

4 – Prevent excess glue stains. ...

5 – Measure with a drafting square. ...

6 – Keep a clean, orderly workspace.

4.3 Saw mill rules

CENTRAL EMPOWERED COMMITTEE

By an order dated 9th May, 2002 the Supreme Court constituted a **Central Empower**ed **Committee** (CEC) for the purpose of manufacturing the implementation of Court orders and other related issues. By another order dated 29/30th October, 2002 the Supreme Court prohibited the States or Union Territories from permitting any unlicensed **saw mills**, veneer and plywood industries to operate without permission of the **Central Empower**ed **Committee**.

The Supreme Court constituted a Central Empowered Committee and issued directions from time to time. One of the directions issued by the Supreme Court on 29.10.2002 was as follows:-

"No State or Union Territory shall permit any unlicensed **Saw Mills**, veneer, plywood industry to operate and they are directed to close all such unlicensed unit forthwith. No State Government or Union Territory will permit the opening of any **Saw Mills**, veneer or plywood industry without prior permission of the **Central Empower**ed **Committee**. The Chief Secretary of each State will ensure strict compliance of this direction. There shall also be no relaxation of rules with regard of licence without previous concurrence of **Central Empower**ed **Committee**. It shall be open to apply to this Court for relaxation and or appropriate modification of orders que plantations or grant of licenses."

For opening of any **Saw Mill**, prior permission of the **Central Empower**ed **Committee** is required. Without such permission and appropriate licence from the competent authority, no **Saw Mill** can be allowed to run in any of the area, particularly in the residential area.

So the running of the **saw mill**, that is established after 29.10.2002 without clearance from the **Central Empower**ed **Committee** is prohibited by the Hon'ble Apex Court.The said Rules have been duly approved by the **Central Empower**ed **Committee** constituted and as per the orders of the Hon'ble Apex Court, a ban was imposed with regard to opening of new **saw mills** and other wood based industries. Even the renewal of licence was directed to be

considered by the **Central Empower**ed **Committee** till appropriate Rules are framed by the State Government.

The Central Government constitutes a statutory agency as contemplated by Section 3 of the Environment (Protection) Act, 1986, an authority was constituted at the national level called Central EmpoweredCommittee [hereinafter the Empowered Committee] for monitoring of implementation of Hon'ble Court's orders and to place the non-compliance cases before it, including in respect of encroachment removals, implementations of working plans, compensatory afforestation, plantations and other conservation issues.

(2) The Empowered Committee shall comprise of a Chairman to be nominated by Ministry of Environment and Forest [MoEF] in consultation with the Amicus Curiae. It will have one nominee of the MoEF, and two NGOs (also to be nominated in consultation with the Amicus Curiae.

As per Notification No. 2 of the Central Empowered Committee (No 1-1/CEC/2002) the provisions and procedures pertaining to an Application are as follows:

Any person shall be at liberty to move the Central Empowered Committee, hereinafter referred to as the Committee, by filing an application for seeking suitable relief against any action taken by the Central/State Governments or any other authority, regarding: (a) deforestation, encroachments, working of the wood based industries, Working Plans, compensatory afforestation, plantations, regeneration, illegal felling and transportation of timber, illegal mining in forest area, and any other conservation issue; and (b) the implementation of the Indian Forest Act, 1927, Wildlife (Protection) Act, 1972, Forest (Conservation) Act, 1980, Environment (Protection) Act, 1986 and the National Forest Policy, 1988including the Rules, Regulations and Guidelines framed there under;

Each State Government should constitute within one month an Expert Committee to :

(i) Identify areas which are “forests” irrespective of whether they are so notified, recogniged or classified under any law, and irrespective of the ownership of the land of such forest;

(ii) Identify areas which were earlier forests but stand degraded, denuded or cleared and

(iii)Identify areas covered by plantation trees belonging to the Government and those belonging to private persons.

Each State Government should within two months, file a report regarding –

(i) The number of saw mills, veneer and plywood mills actually operating within the State, with particulars of their real ownership;

(ii) The licenced and actual capacity of these mills for stock and sawing;

(iii) Their proximity to the nearest forest;

(iv) Their source of timber.

Each State Government should constitute within one month, an Expert Committee to assess:

(i) The sustainable capacity of the forests of the State qua saw mills and timber based industry;

(ii)The number of existing saw mills which can safely be sustained in the State;

(iii)The optimum distance from the forest, qua that State, at which the saw mill should be located.

The Expert Committees so constituted should be requested to give its report within one month of being constituted.

Each state government would constitute a Committee comprising of the Principal Chief Conservator of Forests and another Senior Officer to oversee the compliance of this order and file status reports.

THE STATE LEVEL COMMITTEE may consists of Principal Secretary (Forest), Principal Chief Consrvator of Forests, Regional Chief Conservator of Forests, MoEF. The committee is empowered to evolve its own procedure and co-opt any officer as a special invitee for the purpose of compilation/verification of the information. The Principal Secretary Industries, In-charge of the wood based industries shall ensure that all the information sought by the committee in respect of the Plywood/vener units is immediately made available."

THE DISTRICT LEVEL COMMITTEE FOR SAW MILLS. The District Level Committee pertaining to saw mills was ordered/directed by the State Level Committee to have the District Magistrate of the District its Chairman and the Senior Superintendent of police/Superintendent of police and the Divisional Forest Officer of the district as members. The task assigned to this committee was the collection, compilation and the verification of the informations of saw mills of the district in compliance of CEC's directions

Example.

All saw mills, veneer mills and plywood mills in Tirap and Changlang in Arunachal Pradesh and within a distance of 100 Kms. from its border in Assam should also be closed immediately. The State Governments of Arunachal Pradesh and Assam is to ensure compliance of this direction.

FOR THE STATE OF JUMMU AND KASHMIR

No saw mill, veneer or plywood mill would be permitted to operate in this State at a distance of less than 8 Kms. from the boundary of any demarcated forest areas. Any existing mill falling in this belt should be relocated forthwith.

In Tamil Nadu as per The Tamil Nadu Regulation of Wood Based Industries Rules, 2010.Section 4 (3). No licence for setting up new wood based industries within a distance of two Kilometres from the boundary of any 'forest' whether notified or not, shall be granted, except when it is required for Departmental use. The distance of two kilometers shall be computed from topo sheets as aerial distance as crow flies.

As per sec 2. (f) *"Licencing Officer"* means the District Forest Officer or Wildlife Warden or Deputy Director of Tiger Reserve or Divisional Forest Officer having territorial jurisdiction over the area in the district;

(g) *"Principal Chief Conservator"* means the Principal Chief Conservator of Forests, Tamil Nadu;

(h) *"Wood based industries"* means saw mill, veneer industries, plywood industries, particle board units, Medium Density Fibre Units, block board units, paper pulp and rayon units and includes any other unit involved in cutting, re-sawing or converting timber.

The Tamil Nadu Government has framed Rules namely, Tamil Nadu Regulation Wood Based Industries Rules, 2010 (herein after called "the Rules") under Section 26 r/w Sections 35 and 63 of Tamil Nadu Forest Act, 1982. As per Rule 3 of the said Rules, no person shall establish or operate any wood based industries including the existing unit, unless a licence is obtained

in accordance with these Rules from the District Forest Officer as the licensing authority under these Rules. Therefore, the petitioner shall obtain licence under Rule 4 of the Rules from the District Forest Officer, the licensing officer and also shall get clearance from the Central Empowered Committee for running a saw mill.

5. Grading of timber and Timber products

Comercial grading, stress grading, existing Indian standards for Grading'
Timber Classification

The terms timber and wood are often used synonymously, but they have distinct meanings in the building industry. Wood is the hard, fibrous material that makes up the tree under the bark, whereas timber may be defined as a wood which retains its natural physical structure and chemical composition and is suitable for various engineering works. Following is the classification of timber as per IS: 6534.

Timber Classification on The Basis of Grading

All grading specifications are clearly distinguished between *structural* or *stress* grading, and *commercial* or *utility* grading based on Indian Standard classification.

Structural Grading

It is also known as ***stress*** grading. However, there is a small distinction between the two. Structural grading refers to the principle by which the material is graded on the basis of visible defects which have known effects on the strength properties of the material.
Stress grading refers to the principle by which the material is graded by consideration of maximum principle stresses to which it can be subjected.
Structural grading is further divided as:

1. Grading based on known effects of defects and estimating accumulative value.
2. Machine grading.

Commercial Grading

It is also known as *yard* grading or *utility* grading refers to the principle by which the material is graded by consideration of usefulness of the material and price factors.
Commercial grading is further divided in the following classes:

Grade A: It is based purely, and sometimes arbitrarily, on dimensions and general appearance. The dimensions of lengths and girths for logs, or lengths, widths and thicknesses of converted material are measured according to specified methods. This system is prevalent in Kerala and Mysore. Under these classifications, teak is placed in four grades with two sub-classes in each grade. In the case of other hardwoods, there are similarly four grades in Mysore (Coorg) but the dimensions are fixed separately for each of the species. In Kerala, there seem to be only two grades of hardwoods

Grade B: It is based on the best ultimate use of logs or converted material. Such a system is mostly prevalent in Andhra Pradesh and some parts of Tamil Nadu, and seems to be one of the quickest systems of grading and marking. The logs are classified into grades on the best use possible as for beams, planks, scantlings, etc, and each grade is further divided into 'A', 'B' and 'C' classes to indicate occurrence of defects. Only two lengths are recognized; 'long

(that is, 5 m and above) and ‘short’ (that is, under 5 m). Each log is thus quickly stamped with the first letter of the grade classification, the sub-class, and ‘L’ or ‘S’ for ‘long’ and ‘short’, for example, BAL and PBS indicate, respectively, ‘ beam, A-class, long ’ and ‘planks, B-class, short’. Sometimes another letter is also added to indicate the species, for example, ‘T’ for teak.

Grade C: This classification is based on qualitative evaluation of defects and rough estimate of out-turn of utilizable material. It is prevalent in Madhya Pradesh.

Grade D: It is based purely on evaluation of ‘units of defects’ and fixing the -number of units permissible for a standard volume in each grade. Such practices are common in the Bombay region; sometimes an estimated out-turn is also indicated in each grade. In general three grades are distinguished for various categories of logs and sawn timber. Sizes and other dimensions are also fixed in a few cases, separately for different species and different depots in the same state. This system is being increasingly adopted in the specifications of Indian Standards Institution, and in international grading specifications. This system has a distinct advantage of evaluating cumulative effect of defects in a particular grade.

Structural **timber** is generally sold as a (**stress**) **graded** product. A **stress grade** is the classification of a **timber** when used in structural applications. **Stress grades** are derived from either visual- or machine-**grading**, which specify the **stress** limits that apply to **timbers** used for structural applications.

6. Suitability of Indian Timber for Railway sleepers

Properties required:

1. Wood for railway sleepers should be durable in order to withstand the attacks of fungi and insects and the climate influence to which it is exposed.
2. It should be hard and tough enough to resist the cutting action of the rail placed on it and the strain to which it is subject by the consent passing of heavy traffic over it.
3. The wood should be free from shakes and other defects, sound, free from sapwood and not liable to wrap and split.
4. Adequate strength to withstand the load without failure.
5. The wood should resist wear and tear.

Acceptable species:(Southern zone)

Naturally durable hardwoods requiring no preservative treatment (provided only heart wood is used).

Hardwickia binata (Anjan)
Hopea glabra (Kong)
Hopea Parviflora (Kong or irumbogam)
Lagerstroemia lanceolata (Benteak)
Mesua ferrea (Nangu)
Pterocarpus marsupium (Vengai)
Xylia xylocarpa (Irul)

b) Species requiring preservative treatment.

Acrocarpus fraxinifolius (Mundani)
Albizzia lebbek (Kokko, Vaghai)
Albizzia odoratissima (Kalasiris)
Anogeissus latifolia (Axlewood)
Artrocarpus hirsuta (Aini)
Calophyllum elatum (Poon)
Cullenia excelsa (Pullampalli)
Dillenia pentagyna (Kodapanna)
Dipterocarpus bourdilloni (Karanjily)
Eugenia gardeneri (Jamun or Nayal)
Crewia tilaefolia (Dhaman)
Kingiodendron pinnatum (Kolavu)
Mangifera indica (Mango)
Poeciloneuron indicum (Sayal)
Palaquim ellipticum(Pali)

Metal sleepers versus wooden sleepers:

a. Advantages of metal sleepers:

1. Last much longer than wooden sleepers.
2. With metal sleepers the gauge has not the tendancy to spread that it has on wooden sleepers owing to the wear on the latter.
3. The ballasting of the line is less expensive.

b. Advanatges of wooden sleepers:

1. Wooden sleepers enjoy popularity for the cushioning effect on the track. They absorb shock to a greater extent and make a smoother running road than metal, thereby making travelling more comfortable and causing less wear and tear to the rolling stock and to the rails.
2. Sit well on the ballast and maintain good line of surface.
3. Cheaper than metal sleepers.
4. Less liable to damage in transport.
5. Minor accidents, due to the breakage of sleepers are less frequent where wood is used than where metal is employed.
6. For service in most regions, th wooden sleeper has no rival.
7. Metal sleepers corode rapidly in saline soil and hence only wooden sleepers can be used in such cases.
8. Valued for their sound-absorbing properties, insulation against electricity, spike-holding capacity and for the case with which the rail seat can be changed.

Cheif drawbacks of wooden sleepers are:

1. Decay due to fungal and insect attack.
2. Liability to mechanical wear.
3. Development of shakes and splits in seasoning and in service.
4. Inability to resist fire damage.

Sleeper specification

1. The sleeper should be sawn from one of the approved species.
2. It should be cut from well matured and clean grown wood.
3. It should be cut from a log which is sound and free from rot. On being hit with a hammer it should give a clear ringing sound.
4. It should not contain more than 40% sapwood.
5. The permissible sapwood (measured along a surface in a direction at right angles to the length of the sleepers) for 1st class sleeper is about 25% of any surface dimension under railseat and elsewhere upto 33.3%. For 2nd class sleeper upto 33.3% of any surface dimension under railseat and elsewhere upto 50%.
6. Centre-heart should not be included in both the ends. When included on only one face of the sleeper, it should not be further than 2" for B.G. and 1&1/2" for M.G. and N.G. from the nearest broad face.
7. In the rail - seat region the diameters of all knots (live or sound knots) put together should not exeed 3".
8. knots should not be so clustered as to make the sleepers liable to breakage . No knot should fall on the spike line.
9. Loose or hallow knots under the rail seat is not permissible. so also is the case with decayed or unsound knots.
10. All type of cracks, shakes and splits should be such that they do not fall likely to extend in the near future towards spike.
11. Sleepers with winding or wandering heart line not visible thruogh out its course or appearing in both the broad faces or appearing in the rail seat region are not acceptable.
12 If the decay can be chistled down to the sound wood within 1/3" at the region of the rail seat and 2/3" else where , it is permissimible.Sleepers with decay exeeding above limits are rejected.
13. Border hloes up to 1/2" diameter is permissible provided their number dees not exeed one per sq. foot of peripheral area. No border hole should not fall on the spike line.
14. Nosleepersshoild be undersize in width and in depth together.
15. The sleeper should be level in plan elevation.
16. Both ends must be squared and clean.

6.1 PACKING CASES

Requisite qualities

Wood for packing cases shoild be light , easily worked and fairly soft so that nails can easely be driven in without causing the wood to split, while the wood should contain no colouring matters or other substances likely to injure the content of the box. It should be free from objectionable odour and should be reasonably cheep.

Suitable species.

Bombax ceiba
Tetrameles nuduflora
Dysoxylum malabaricum
Mangifera indica

Hyminodicktylon excelsum
Polyathia fragrans
Annacodium occidentale
Terminalia belarica.

6.2_Sports goods , musical Instruments

a .Hocky sticks

Qualities required

The properties required for the wood for Hockysitckstoughness , hardness and elasticity.Woodshpild be straight grained which will stand up to the process of bending without cracking and splitting, easy to work and finish, capable of taking good polish.

Suitable timbers.

Morus alba
Celtis australis
Dalbergia sissoo
Fraxinus species.

b. Cricket bats.

Toughness , hardness, and elasticity combined with light weight are essential qualities required for the wood.

Suitable timbers.

The Kashmir willow from which cricket bats are made in India is a hybrid species of Salix alba xS. fragilis. Salix babilonica is also used for cheap type of bat.
Populus euphratica(Indian popular)
Sapium sebiferum(Chinese tallow tree)
Jacaranda mimosaefolia

c. Stumps and bales.

Morus alba
Grewia teliaefolia
Polyolthia fragrans

d. Tennies raquets (Also badminton and squash raquets)

Wood for raquets should be long fibered and straight grained and should not crack or split whole bending.

Suitable timbers

Dalbergia sissoo
Juglans regia
Morus alba
Toona ciliata - for the wedge and handle part.
Swietenia mahogani - for the wedge and handle part
Swietenia macrophylla - for the wedge and handle part.

e. Billiard cues.

Wood must be of light weight and must have a long fibered straight grain; and also free from defects such as small knots or flecks.Weight required is about 42.lbs per cu.feet. It should be free from warping.

Suitable species.

Diospyros melanoxylon
Grewia tiliaefolia
Polyothia fragrans

f . Golf clubs

Straight combined with toughness asnd elasticity are essential requirements for the wood.

Suitable species

Terminalia species
Grewia species
Anoguissus species

For Golf culb heads

Xylia dolabriformis
Musua ferrea
Acacia arabica

g. Bows and arrows..

Strong , tough and elastic wood is required for bows.

Species suitable

Acacia catechu
Grewia species
Berria ammonilla
Sageraea listeri(Andaman bow woos)

Arrows may be made of any strong wood which will remain straight and not warp.Reeds and Bamboos are very suitable for the purpose.
Other suitable species are
Dalbergia sissoo
Gmelina arborea
Pterocarpus marsupium
Calophyllum species.

h. Fishing rods

Wood must be strong ,plioable and elastic.

suitable species
Caryota urens
Acacia catechu

Dendrocalamus strictus.

i . Skis.

Toughness , flexibility even texture and straight grain are the essential features for a good ski.

Species suitable for Skis

Dalbergia sissoo
Anoguissus latifolia
Fraxinus floribunda.

MUSICAL INSTRUMENTS

Requisites

The wood would have uniform annual zones(preferably 1.5 to 2 mm and summer wood 1/4 to 1/5 of the zone); even structur, without any knots or other flaws which will injure the tone. Wood should be light (about 25 lbs per cft) ; free from resin.

Suitable Species

(a) For Piano cases

Ornamental woods such as
Juglans regia
Chloroxylons wietenia
Swietenia mahagoni
Tectona grandis
Pterocarpus dalbergioides

(b) For Harmoniums , organs ets

Tectona grandis

(c) Violins

Piecea smithiana
Pinus Wallichiana - for bodies
Pinus roxburghii
Tectona grandis
Dalbergia latifolia - for keys
Diospyros ebenum
Dalbergia latifolia - for bows

(d) Sitars

Tectona grandis - for neck
Cedrusdeodar - for keys
Dalbergia sissoo
Toona ciliata - for bodies

(e) Guitar

Body
Canarium euphyllum
Grewia teliaefolia – Indian Linden
Mahogany

Neck
Rosewood

(f) Drums and tom - toms

Pterocarpus marsupium
Garuga pinnata
Morus alba
Artocarpus heterophyllus
Madhuca indica
Dalbergia sissoo
Trewia nudiflora

6.3 AGRICULTURAL IMPLEMENTS

(Ploughs , harrows, rollers and clod-crushers)
A strong, hard, tough timber is required for the type of work.

Suitable Timbers.

Acacia Arabica.
Anogeissus latifolia.
Cassia fistula
Chbroxylon swietenia
Syzygium cumini
Dalbergia sissoo
Grewia tiliaefolia
Ougeinia oojeinensis
Prosopis spicigera
Schleichera trijuga
Xylia xylocarpa
Zizyphus mauritiana

TOOL HANDLES

(a) Carpentary tool handles

Qualities Required
Closeness of grain, toughness,hardness, and non liability to split. The wood must be hard enough and tough enough to stand blows from a hammer or mallet and must not splinter under such blows.

Suitable timbers

Acacia catechu

Acacia arabica
Mesuabferrea
Tamarindus indica
Schliechera oleosa
Oungeinia dalbergiodes
Anogeissus latifolia
Dalbergia sissoo
Xylia dolabriformis
Pterocarpus marsupium

(b) Axe, pick and hammer handles

Qualities Required for the wood.

Strong, hard, tough and elatic:straight-fibred and capable of withstanding the continuous shocks resulting from the use of tools.

Suitable species .

Anogeissus latifolia
Grewia tiliaefolia
Acacia arabica
Mesua ferrea
Shleichera oleosa
Dalbergia species
Diospyros species
Terminalia tomentosa

6.4 FURNITURE INDUSTRY

Qualities Required

Wood must be light, strong , elastic and tough.

Sustainable timbers.

Tectona grandis
Dalbergia latifolia
Dysoxylum malabarcium
Artocarpus heterophyllus
Arcocarpus fraxinifolius

Camp furniture

Strength and lightness are required.

Suitable timbers

Fagara budrunga

Atalantia monophyllia

Morus species

Dysoxylum malabaricum

Albizzia procera

6.5 Coach building and sleeper industry

Railway carriages

Qualities Required

wood to be used in railway carriagges and wagon work should be sufficiently strong and durable for the purpose in view. It should be free from bad seasoning defects, and should be available in sufficient quatities.

Suitable Species

Tectona grandis (Main timber used railway wagon and carriage works)
Shorea robusta
Pterocarpus dalbergioides
Cedrus deodara
Dalbergia latifolia
Acacia arabica(pillars: fromaing and floor-boards).