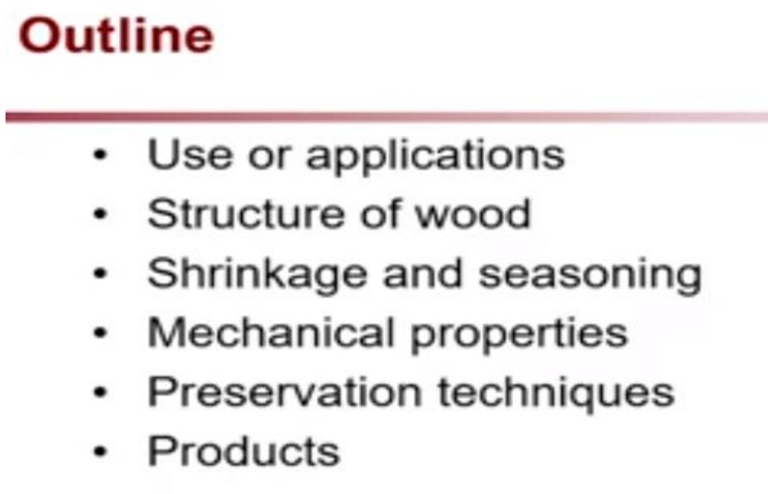
Basic Construction Materials
Prof. Radhakrishna G.Pillai
Department of Civil Engineering
Indian Institute of Technology, Madras

Module No # 10
Lecture No # 49
Wood and Wood products – Part 1

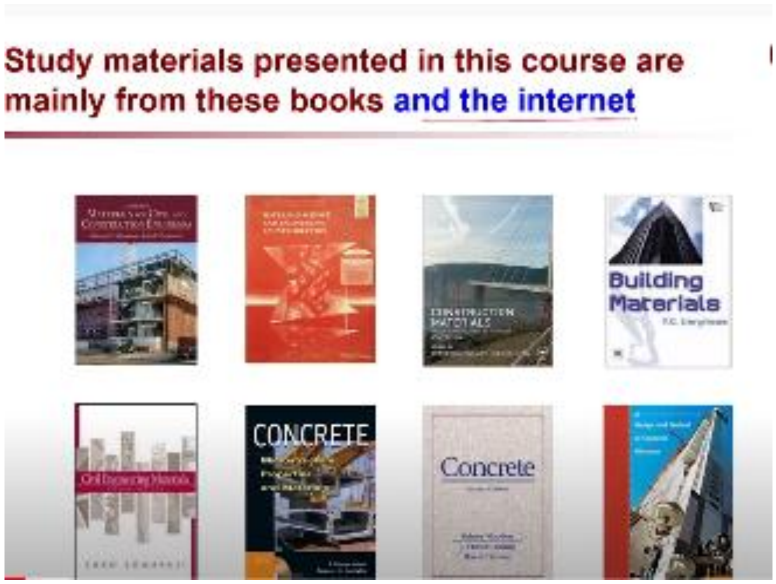
Hi, I am Radhakrishna Pillai from IIT madras; this lecture will cover wood and wood products today as part of this MOOC course on basic construction materials.

(Refer Slide Time: 00:29)



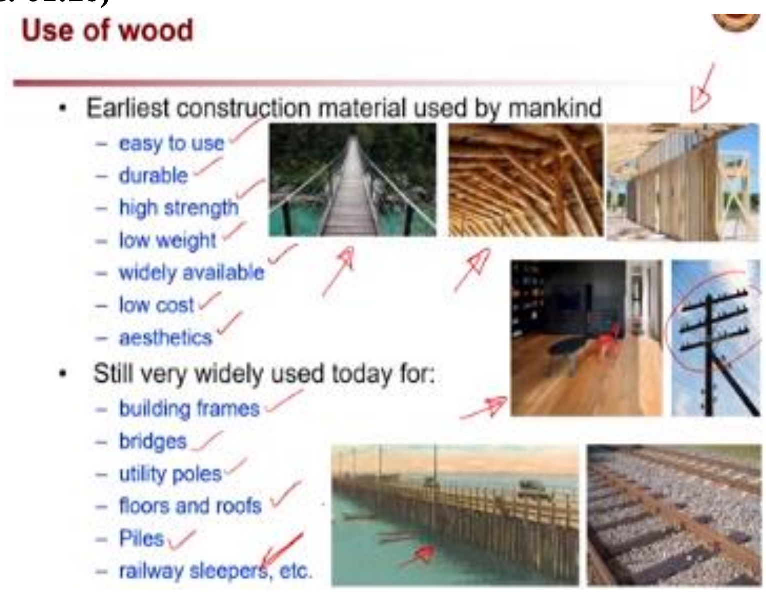
And we will talk about the use of wood applications, and then we look at the wood structure; how is it made? And then look at shrinkage and seasoning like shrinkage related problem and then how to address that one of the methods is by seasoning. And then look at the mechanical properties of wood and then also very briefly on preservation techniques. And a couple of products and then even when we talk about those products how the damage mechanism, etc., will also be discussed.

(Refer Slide Time: 01:06)



As I have been telling through this course, we used inputs from various textbooks as we see here many photographs, etc., have been used from the internet.

(Refer Slide Time: 01:20)



Now use of wood or the where do we apply or use this you know to use wood? So it is one of the earliest construction material used by the mankind one. We were using it because it is easy to use and durable, and has high strength, depending on which direction you are used. And, what you are using it for or what type of load is applied in which direction it is applied, all that we will discuss in detail in the coming slides.

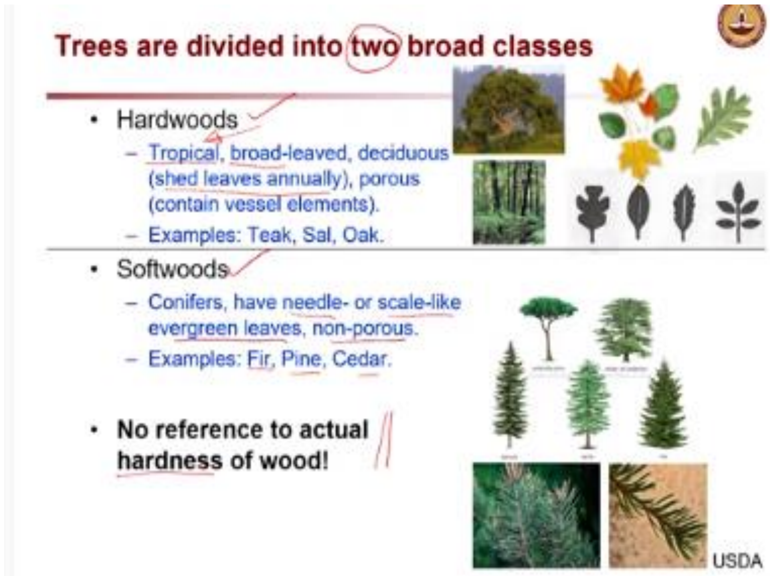
And also, it is lightweight, so we talked with easy to use, durable, high strength, low weight, and widely available. Low cost, and it also looks good because of the grains and the structure, which is, I mean the design grain structure and all that gives you a good look. And relatively low cost compared to, I mean the cost always depends on many other factors, so you know. However, generally, we can say it is cheaper when if it is available in plenty.

Now still very widely used for building frames you can see the picture on the top right corner here building frame, here this is another. And then bridges also utility poles you know like electrical lines and etc. Nowadays, we see more and more of these wood or Timber products, I mean. We are starting to use reinforced concrete of pre-stressed concrete poles depending on the load-carrying capacity required.

Sometimes wood may not be sufficient to handle, and at the same time, the availability of wood may not be that easy. So we go for reinforced concrete and talk about many such products, so concrete is also being used nowadays. And then floors and roofs for the floor you can see here are mainly very good for you know people at home. If they are old and then the floor will not be very cold is suitable for both summer and winter conditions like cold and hot climates.

Wood would seem to be a good option rather than some tiles or marble floors etc., and you can because there are advantages for health reasons. And then piles for you know bridges, or you know anything which is going you know water body you know. And then railway sleepers this is widely used but now again it slowly it is changing to reinforced concrete or pre-stressed concrete systems. Because of the load requirements or higher better capacity requirements for the sleepers, it has been used widely earlier.

(Refer Slide Time: 04:28)



Now trees, in general, can be divided into two broad classes: hardwood and the other one is softwood. Hardwood is generally available in tropical climate conditions. Generally, the leaf structure, you can see the top half of the screen and bottom half of the screen; there is a strikingly different structure or visual appearance; I mean, the appearance is very different of the leaves.

So in the case of hardwood, it is broad leaves and deciduous, which means they shed leaves annually and they are porous in structure. And examples are teak, Sal, oak etc., which comes under the class of or category of hardwood. Then we have softwood like conifers and have a needle-like, or scale-like evergreen leaves nondeciduous and then nonporous also examples are fir, pine, cedar, etc.

In these two classifications, you can look at the geographical location or climatic conditions these two types of woods are present. One more important thing is that this name hardwood and softwood does not reflect on the mechanical hardness of the wood. This hardness of the wood has nothing to do with this; terminologies of hardwood and softwood, remember that.

(Refer Slide Time: 06:09)

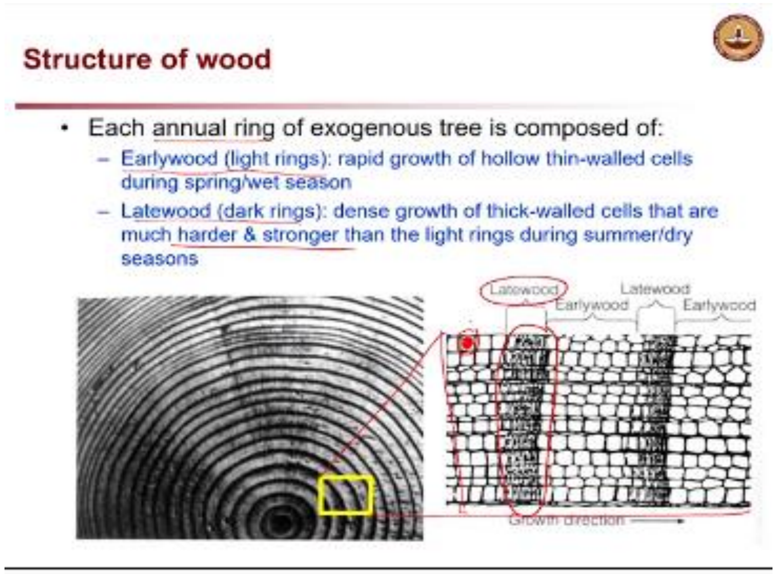
Then what are the types of wood species available in India? We generally used teak a lot because it easy to work with; if you ask a carpenter, you know what is the advantage of using teak wood ? They will say it easy to work; in other words, you do not need much energy chisel or to work with that to cut that wood to work with that wood. So easy to work with that is if you are the carpenter.

So also another technical reason is it has good dimensional stability, which means it does not shrink or swell, you know, as a function of time. It does not shrink or swell as much as another type of wood, and it is durable; that is why it is very costly also. Then density also matters. So Padauk is another type where it is medium-density hardwood color also matters. So you can look at this list here. It is not something to memorize; it is just for you to feel what type of Timber or wood is available in our country?

Then what are the properties you should look for also? Color is one thing because aesthetics is the function which we look for. And also, the dimensional stability, strength, and ease of working with the Timber are things we should worry about. I have been using the word Timber and wood in between; if you look at the definition for Timber is nothing but a processed wood.

But more or less, I do not think it matters you can use both words but Timber in general when we say it is a processed wood. Other types are Sal, deodar, and rosewood; these are all available in various parts of our country.

(Refer Slide Time: 08:14)



And now, let us look at the structure of wood so you can see the picture on the bottom left; this is the typical cross-section; if you cut a tree, you will see the rings like this. Each ring represents one year each ring in this, so by looking at this cross section of the wood, we can tell the age of that wood or age of that tree. Look carefully at the picture; you can see earlywood, which is light rings, and latewood, which is dark rings.

Now on the bottom right side you have a close up image of this yellow region which are shown in the left side image. It is a closeup view on the right now you have a closeup view; something like this is a closer view of the yellow region. Look at this dark and light color and the dark color rings; it is very clearly shown on the right side image. So this region you can see earlywood here these are the light color region and the latewood which are the dark color region.

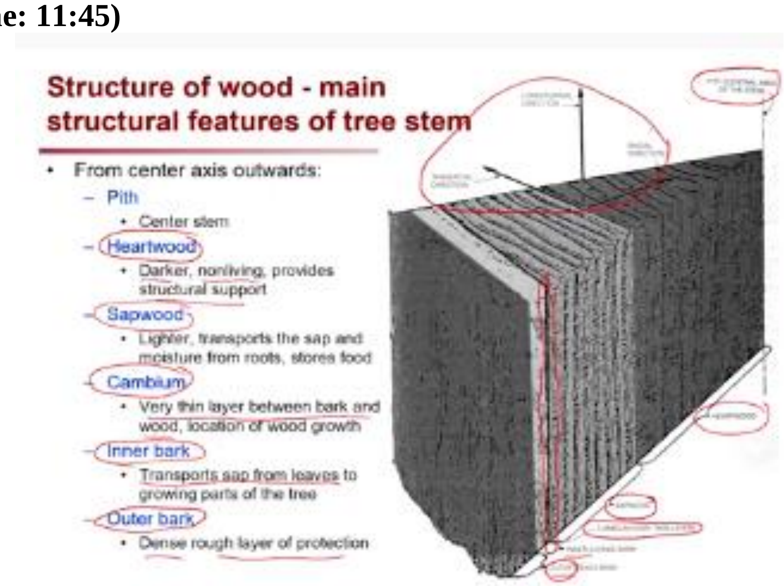
So you can see that latewood is denser like this region and earlywood is less dense, this region is less dense, so that is clear. So two types of in the same when you form the rings now look at this, why this latewood and earlywood? Now earlywood it is like rapid growth of hollow thin-wall cells; this is the earlywood we are talking. In this region, you have larger cell walls; they are hollow, and they grow rapidly during the spring or wet season.

That is when they grow rapidly because whichever cavities are formed that will get filled with this moisture, so they eventually will have a larger cavity. Or the cell structure is like that now when you take about the latewood, which you can think here this denser region and these are thick-walled cells. In the first earlywood, they are thin wall cells now; these latewood are formed during the summer or dry season.

And they are thick-walled cells and smaller in size also the cavities are also smaller. And hence because they are thick walls, they are much harder and stronger than the light rings. So this is the main thing to learn about these different rings and the region of the ring latewood and earlywood which one is stronger, which one is weaker in comparison, and which is formed at which time of the year.

And then the reason for to know the strength is, because you have the thick wall the wall thickness plays a major role and the size of the cavities also plays a major role. If I Look at here, this is the cavity I am talking I am drawing on the picture here; this is the cavity, and this is the wall thickness which I am talking of the wall or the wall.

(Refer Slide Time: 11:45)



Now the structure of the wood main structural features of a tree; if you cut a tree these are all the different parts of a stem. You can see here that the first one is the central axis of the stem; we call it pith. And then you have something called heartwood that is here. I am just connecting the image and the text. So heartwood is the core of the wood is darker. And we say it is non-living and provides the structural support; it is not actively growing or providing the structural support.

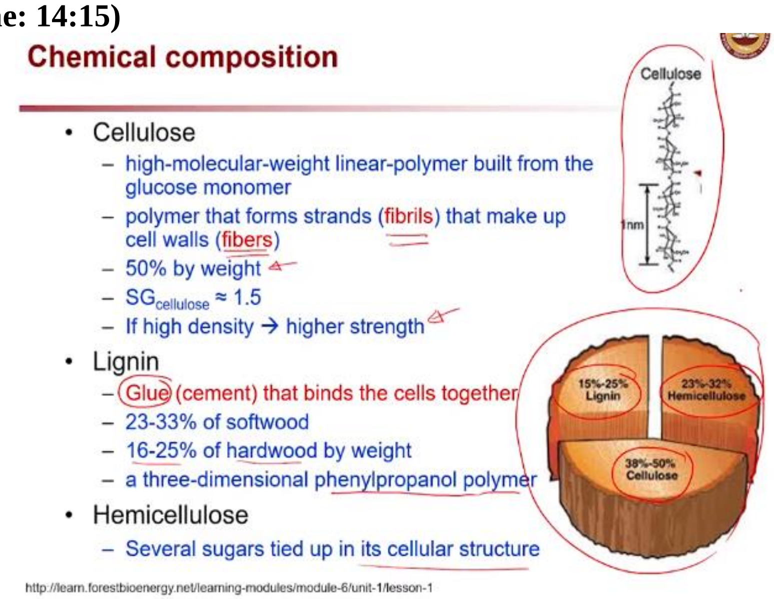
Then you have the sapwood, which is the lighter color region here, and it transports this sap and moisture from the root and stores the food. Then you have cambium as you go, outer and outer;

you have cambium here, the thin layer. So you can see here this layer is what we are talking about this thin layer darker color region you can see there that is the cambium. And what is it is? A very thin layer between the bark and the wood growth of wood growth is where the wood grows laterally

Now inner bark is another bark; look it as the outer shell of the core wood and inner bark and out bark; there are two categories for this; I mean two regions for this bark. So, the inner bark transports the sap from leaves to the growing part of the tree. Now which is that growing part of the tree? That is the cambium we just discussed that. Now outer bark is the dense or rough layer just to protect this portion here; it is just for protection.

So this is in general, if you take Timber or cut wood, you can look at the cross-section, and you can see these different regions or you know on a wood. Now there are, also another important thing that we need to look at is a direction longitudinal direction, tangential direction, and radial direction. I will discuss this later but remember that the property is changed as we look at Timber in different directions.

(Refer Slide Time: 14:15)



Now chemical composition what is the chemical composition? In general wood, you can look at the graph on the bottom right; there are three key components. One is cellulose which constitutes about 40 to 50%, and then you have hemicellulose, and then you have lignin. So composition, you can see cellulose is the major component, and then you have about 20 to 30% hemicellulose and then 15 to 25% lignin.

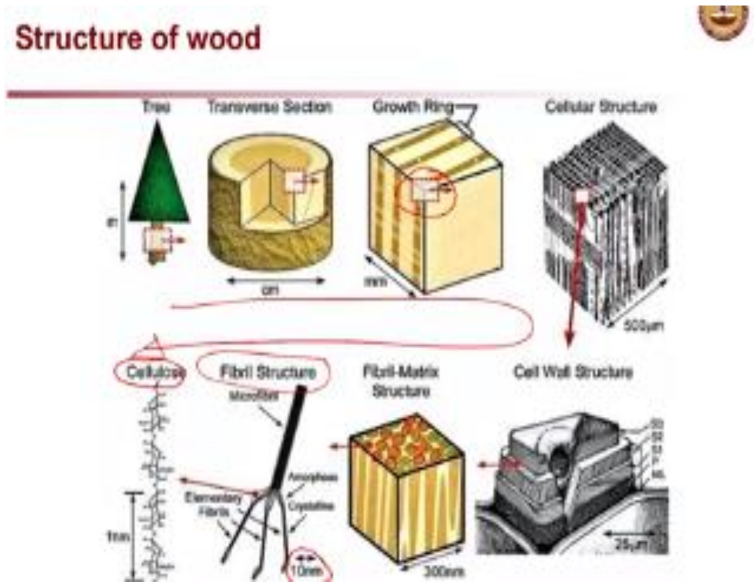
What are these three things cellulose? What is it? It is a high molecular weight linear polymer built from glucose monomer that is in the general description of what cellulose is. You can see a non-polymer structure here. And then polymer that forms strand fibrils that make up cell wall fibers these two things I will talk about in the next slide. These fibrils and fibers you will see in the next slide the same image I will show again.

Now 50% by weight of wood is because of the presence of cellulose, and its specific gravity is about 1.5 so in if high density and that leads to higher strength also. Now lignin you know you have it is basically the glue that binds the different cells together, or the cementations property essentially, it is the glue that is what it is. And it is 23 to 33% of softwood and in case if it is a hardwood then.

So these numbers in I am not expecting you to memorize these numbers because this will vary from wood to wood. But just to have a ballpark idea about how much the composition is etc. Now, what it is lignin, a 3-dimensional phenyl propanol polymer. Anyway, so this general idea only now hemicellulose several sugars tied up in its cellular structure. So this is how the chemical composition main thing is to look at which are the key components?

Which are the key components? And what are roughly the proportion and their role? So all the most the properties are you know provided by the cellulose and lignin place like a role of combining or binding these cells together. And you know hemicellulose is well whether different sugars are tied up in a cellular structure, so this is the chemical composition.

(Refer Slide Time: 16:58)



Now, look at the physical structure of wood as we will start from macro-level to micro-level, which means from the top right top left of the screen to the bottom right of the screen. So let us see a tree you cut a stem of a tree that is this like this if you like that what you will see? Let us say in the range of centimeters, a few centimeters, depending on what you are cutting 10 centimeters.

Or if it is a very large tree, it might be even going into meters anyway, whatever that is. So you take a stem and then look at these red rectangles shown on each of these images here, which kind of indicate the next image that is zoomed in. So from the first image, I have a rectangle here; the second image is how that rectangle looks like the transverse section. So now, if I cut another here, this is showing this thing like that zooming in sequentially getting more, closer, and closer image.

Now the second is very clear now, the third one it is showing, what are the rings which we talked about the growth rings we talked about very clearly you can see the growth rings. You can see the early wooden latewood here, right. So I can see this is the earlywood and latewood. So to re-emphasize that so, you can see here that the denser one is the latewood and the lighter one are the earlywood.

So here you can see this denser one is the earlywood and the denser one is the latewood, and the lighter one is the earlywood denser, late, lighter, early anyway. Now, if you look at this region here, you can see the closeup of that cellular structure here you can see. Again, these cell walls and etcetera are visible here further going so you can also track the size in which you are talking; this is like about 0.5 millimeter.

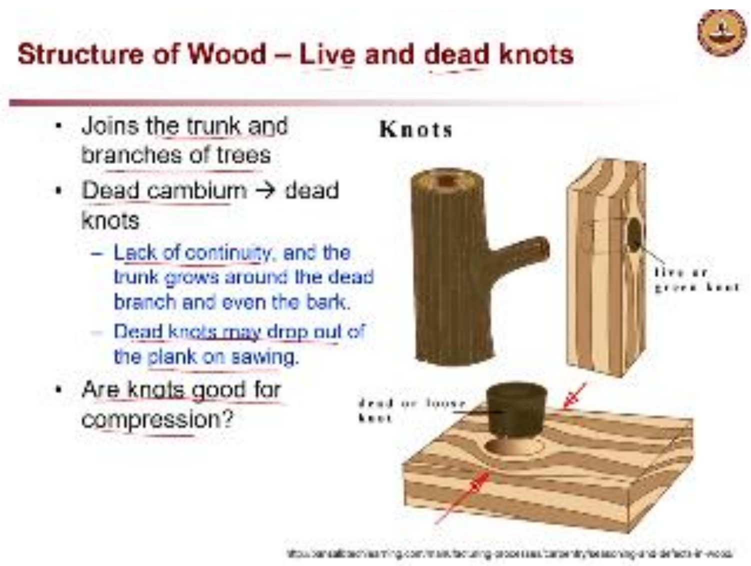
So this very small region, we are talking about this one. Now, if I go to the cell wall structure, I think in the beginning, I told that we would go from top left to bottom right. No, we are going in a clockwise direction, so going like this and then we will go like this. So top left to bottom left that is how clockwise direction we are going. So here you can look at the cell wall structure where you can see different again microstructure levels.

You can see 25 micrometers that mean 0.025 millimeters, so you can see how small we are looking at. Then looking at one of the cell wall elements, this is how the cell wall elements look like. Fibril matrix how the fibrils look like and then you can see that these are all each of those fibrils all these green circles here are individual fibrils. Now next, the image on the left side looking at fibril.

Fibril structure you can see microfibrils and amorphous structure, crystalline structure depending on what type of tree it is? And then you can see it is also very small 0.01 millimeter this is nanometer rights you can see is it is nanometer very small so 10-nanometer scale you are talking about them. Then further, if you go into the chemical structure, you can see cellulose in this picture I already showed in the previous slide.

So this is, in general, the physical structure of wood; you can start from how a tree looks like and into this small chemical structure of the wood.

(Refer Slide Time: 21:59)



When you look at the physical structure, there is something that you might already have seen on wood; there are called knots. And also, there are live knots and dead knots; how do they function, what is the role, how do they influence the wood properties? So what they are essentially is? They join the trunk and branch of a tree so if we can here, this is where a branch is coming out of a trunk or a stem.

And now, if it is an alive or green knot, it will be something like this that means it is active their connected; they are bonded well together. If it is a dead knot like this on the bottom right image, you can see that it is not mechanically bonded to the wood, so it will come off if you try to pull it out. Now, this has a problem, or wood or Timber with this kind of knots may not always be good when you look at mechanical behavior.

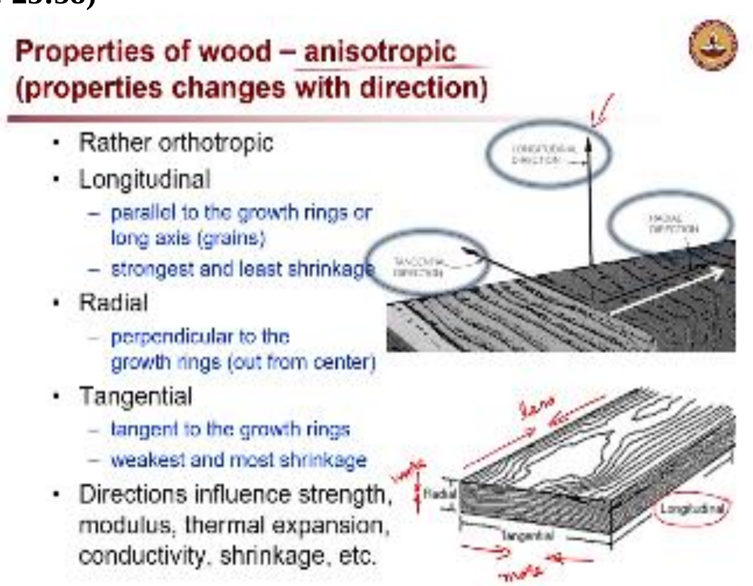
So what happens is why this is happening is? The cambium is the growing part of the wood, and I said thin layer between the bark and the growing and the heartwood. Or the sapwood between the sapwood and the bark so this thin layer of cambium that actually if that gets dead then the knots also get dead because there is no further connection between them. So now, because of that, there is a lack of continuity, so it also affects their stress transfer etc., and the trunk grows around the dead branch and even the barks.

The dead notes may drop out of the plank on sawing. But there are also cases where you might have it inside the wood, but it is not just following off, and it stays there but the way you apply the struggle loading it might have an influence on the behavior. So the question here is, are knots good for compression? Now, look at the picture here if I compress this wood like this.

And like this, if I compress the wood in the direction parallel to the grains. If I compress the wood in the direction parallel to the grains, what will happen is? There will be a lateral force generated here, lateral stress will generate here, and it will hit like this. And it can this the stress concentration will happen here and here, and it will again lead to failure of the wood because of that dead knot there. And also; it will push out also puts out the dead knot, that is one thing.

If I apply load in the other direction, let us say I am applying the load in this direction. Then also, there is a compression, and it might push the knots out. But again, you might experience that there is a stress concentration. But depending on the direction, it might not affect much in this direction but in the other direction, which I showed you earlier. It will have some impact on opening up or in cracking of the wood along the grains or between the grains.

(Refer Slide Time: 25:58)

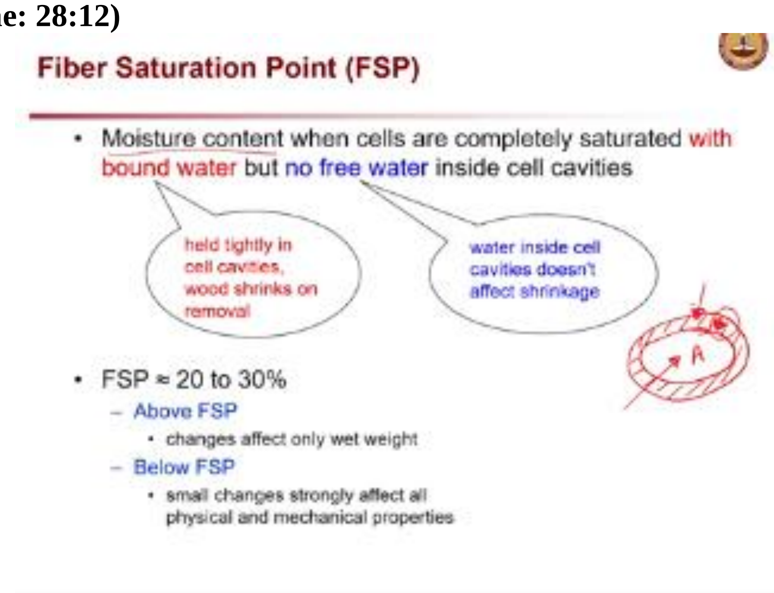


Now properties of wood and they're anisotropic in nature, which means they are very much dependent on the direction. So I would say even somewhat orthotropic in nature but again, let us say it is anisotropic is the keyword which we are talking about here you. Now in the longitudinal direction, this direction is along the stem or along the grains parallel to the growth rings parallel to the axis of the growth rates.

Now they are strong in the direction, and least shrinkage happens in that direction. So that means look at the picture on the bottom right you can see this is the longitudinal direction I am talking. And these are all the grains you can see on this, and along the grains, they do not shrink much. Or shrinkage in this direction is very minimal**.** Now, if you look at the perpendicular direction, either radial or tangential direction.

You will have you know the weakest or weak the strength is weak. In that direction and shrinkage happen mostly in these directions. Shrinkage happened, so this will shrink this way, or it will shrink this way; this is what we are talking about? But the shrinkage in the longitudinal, this shrinkage is very less here it is more here also it is more so I think that is clear. So directions influence the strength, modulus, thermal expansion, and conductivity shrinkage. These mechanical properties are very much different in these three directions of Timber, especially between the longitudinal and the other two directions.

(Refer Slide Time: 28:12)



Now there is something called as fiber saturation point; what is that? So this is the moisture content when cells are completely saturated with bound water. The water which is chemically bound and but no free water inside the cell cavities. So the cell walls, let us say this is the cell wall, so the cell walls here again. So it says cell cavities assume that this is a cell wood cell and these are cell walls.

Now the highly you know the water is held tightly in cell cavities, wood shrinks on removal. This is the bound water you are talking about and the water inside the cavity; the second is that this water inside the cavity does not affect the shrinkage. So first, when you try to dry wood, what will happen is first, let say I am going to call this region A and then the region B. First, what will happen is, the water in region A will evaporate, which is the free water.

And then, after further drawing, that only the water in region B, or that is, the cell wall itself, will start evaporating. Now FSP is about 20 to 30% for most of the wood. So above the FSP, that means if the water you know content if there is still water in the region A, it affects only the weight. And below FSP, what happens if it below FSP means you now start taking the water from the region B. And then the properties start getting affected like physical and mechanical properties will start getting affected.

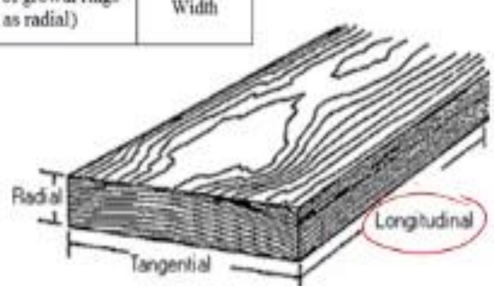
Let me reiterate this once more; let us say you have taken a new wood, you cut it, you are going to process it, and now you have to first dry that wood right. So initially, you will have a lot of moisture in the wood; now, as you start drying first, the water in the inside the cell cavity, that is, the region A, will start drying. At that time, the only change in the wood is the change in the weight of the wood loss of water.

Now, after further drying, when you reach like fiber saturation point at that time, then the water from region B also starts evaporating. And then the properties start changes not only weight but also the shrinkage and mechanical properties starting.

(Refer Slide Time: 31:22)

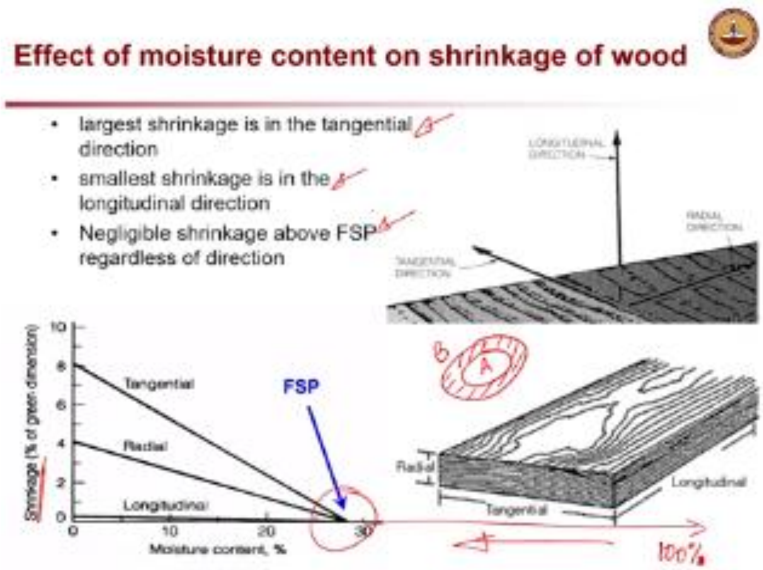
Directions of shrinkage

Longitudinal = Along the grain (Negligible)	Length
Radial = across the growth rings	Thickness
Tangential = in the direction of growth rings (Twice as much as radial)	Width



And now I am going to show you this thing once more; this sketch is to tell you about the direction of shrinkage in the longitudinal direction. We have already discussed this in the longitudinal direction; it is negligible, and in the tangential and radial direction, there is twice as much difference in general.

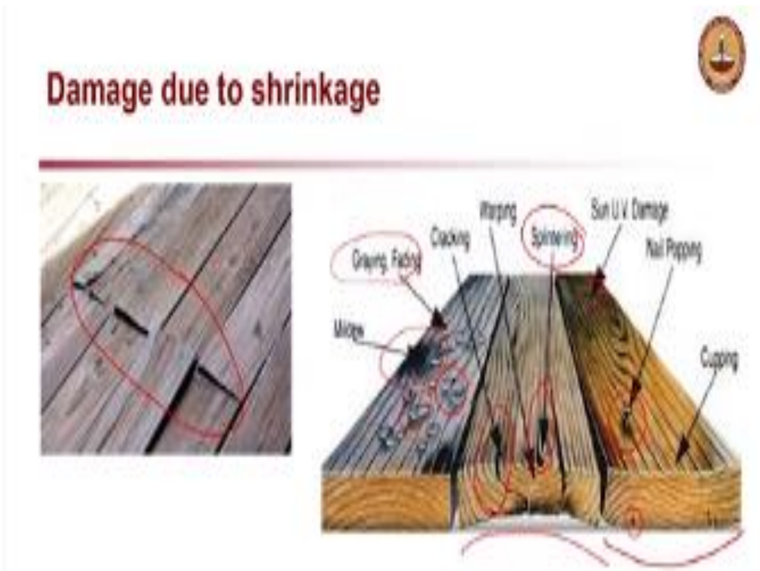
(Refer Slide Time: 31:42)



Now, this is what we were talking about what is FSP. So the let us say I am extending this to the right. Let us say this is about 100% fully saturated wood. Now, what happens you start? You have to go from the right end of the curve graph to the left. So this is how we start drying the wood, so up to about 20 to 30%, that is this region where there is no change in the shrinkage property because the water from the cell cavity is being evaporated.

So this is what I have drawn earlier this is the B region, and this is the A region, so water from the cell cavities is evaporated. So after this 20 to 30%, you can further dry you are, removing water from the wall region that is the B region that leads to change in the properties. So, the largest shrinkage happens in the tangential direction, and the smallest shrinkage in the longitudinal direction. As we discussed earlier and negligible shrinkage above FSP regardless in the direction above FSP, there is no shrinkage happening because it just water from the cavities are being evaporated.

(Refer Slide Time: 33:16)



Now damage due to shrinkage, so you can see here on the left image that there is a pop-out different type of you know if you have been to places where Timber is used for flooring at etc. You will see this kind of problem because of the warping etc. So you can see that the right-side picture kind of shows the different types of problems that are experienced in such structures.

You can see here mildew or some fungal growth etc., is because of the water droplet staying there, and then color also starts changing fading. And then here you can see cracking and then here you can see warping you can see that this wood has turned like this, you know. It is warped; the shape has changed, so the center portion lifts up and splintering you can see here so small grains you know can come out are we call it splintering.

And then UV damage is also sometimes possible, and if you have a nail, if that wood starts, you can see here slight warping in the other direction and then cracking here. So many of these problems we call this behavior cupping on the right side. So when that happens, even the nail can come on. Because of the pressure exerted by the wood itself by this shrinkage action, these are all general problems experienced by wooden wood structures.