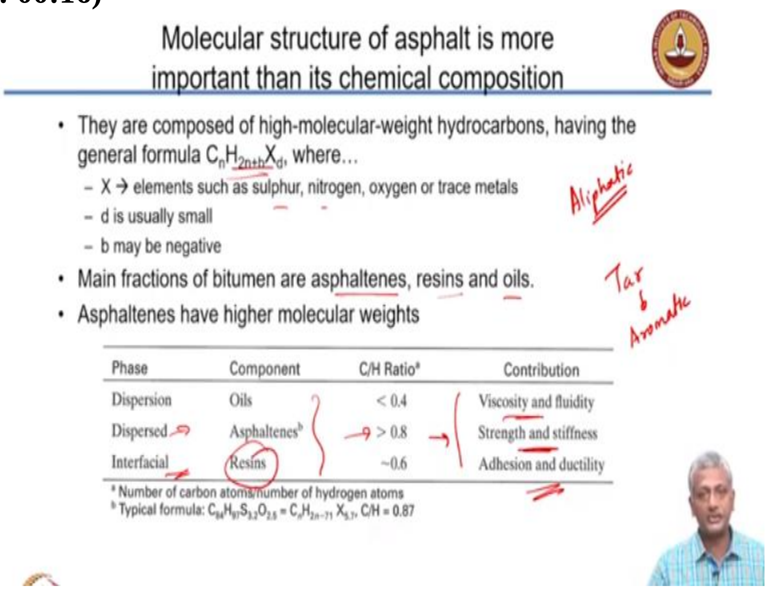
Basic Construction Materials
Prof. Manu Santhanam
Department of Civil Engineering
Indian Institute Technology, Madras

Module No # 10
Lecture No # 46
Pavement Materials 1 – Part 2

(Refer Slide Time: 00:16)



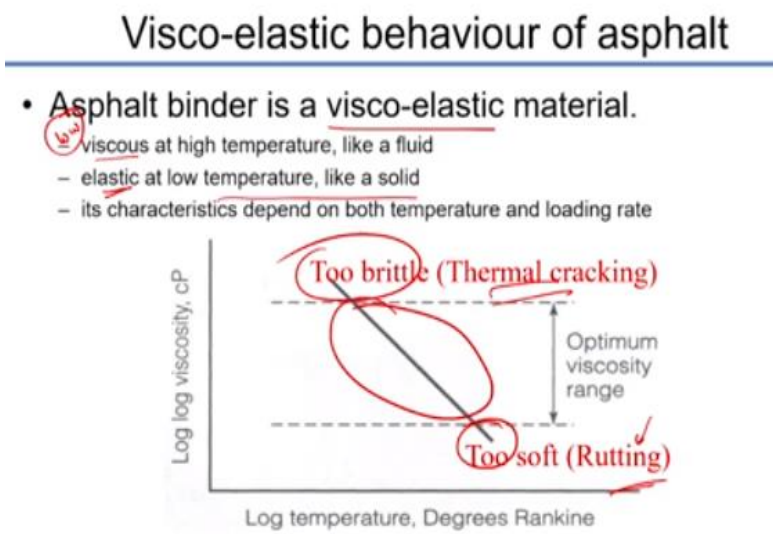
So again, coming back to the structural asphalt, as I said it is a long chain hydrocarbon or aliphatic hydro-carbon, not aromatic but aliphatic hydrocarbon. And this is where it differs from tar, tar is aromatic. So if you remember your organic chemistry, aromatic means it has got the benzene rings in it **w**hereas asphalt has a long chain structure. This is a general formula of asphalt. You can have elements like Sulphur, nitrogen, oxygen or trace metals in the structure of the hydrocarbon itself.

Now asphalt is not as uniform as it looks. It has got a lot of features in it which needs to be looked at carefully to really understand the composition of the asphalt or bitumen**.** This composition is made of with asphaltenes, resins and oils. And these materials differ in terms of the type of hydrocarbon that you are forming or the carbon to hydrogen ratio that you have in the polymer molecules.

And what are these contributing towards as far as the asphalt is concerned? So, for example, you have the dispersing phase, that is the oils, dispersion phase oils which are responsible for fluidity and viscosity. You have the dispersed phase, remember, we also talked about particulate composites, you have the dispersed phase and continuous phase. So continuous phase is the dispersion of the oil in this case, the dispersed phase is your asphaltene.

Here they are responsible for the strength and stiffness of the asphalt. And interfacial phase that are between the asphaltenes and the oil, these are the resins and these are responsible for the adhesion and ductility of the asphalt. So, asphalt looks like uniformly black material, but it is actually composed of several different components which need to be understood carefully.

(Refer Slide Time: 02:10)



Most important with asphalt, it is highly dependent upon the temperature; the application of the asphalt is highly dependent upon the temperature, because asphalt is a viscoelastic material. Remember in the chapter on polymers we talked about the fact that one of the important consideration of polymers is to assess its viscoelastic behavior and the range of temperature over which you can get satisfactory performances as a solid.

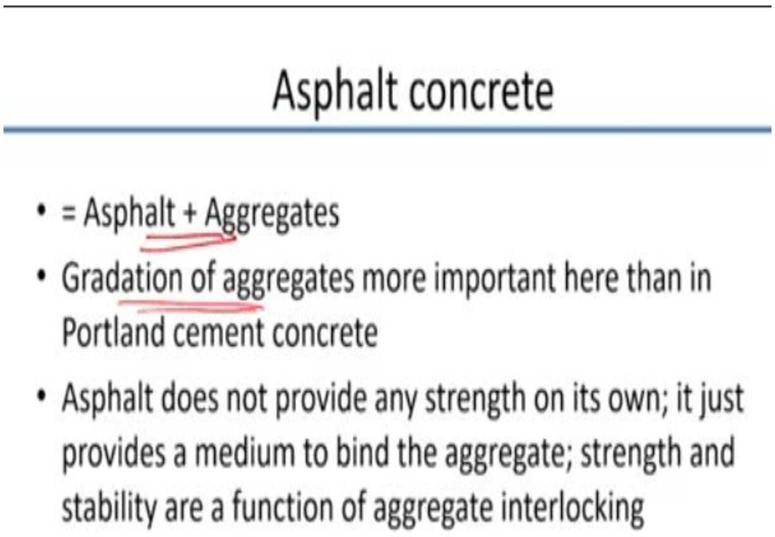
So, it is low viscous at high temperature. It is got low viscosity at high temperature and behaves like a fluid, it flows easily. When you reduce the temperature, it becomes elastic. So from viscous behavior it comes to an elastic behavior, at low temperature like a solid. So, if you come to a very low temperature, if you reduce temperature significantly, we talked about this before that, polymers can become very brittle.

When the temperature is very low, you can get thermal cracking. When the temperature is very high, your polymer will start flowing. So, we get problems in asphalt pavements such as rutting, when the asphalt becomes very soft, at high temperatures. So, you have an optimum range of temperatures over which you can actually work with the asphalt. And that is very important to ascertain by proper testing.

So, characteristics of asphalt like any other polymer will depend on both temperature and the loading rate at which you are performing the experiments. So, it is very important to understand. This is a simple graph it does not show you anything. It says logarithmic scale of viscosity against the logarithmic scale of temperatures gives you a straight-line relationship. Very high temperatures are pointing towards asphalt features, having very less viscosity and causes problems like rutting.

Very low temperatures asphalt becomes very brittle and starts cracking. So thermal cracking at low temperatures and rutting and other associate problems at high temperatures, we will see them later on when we talk about the distresses that you commonly see asphalt pavements.

(Refer Slide Time: 04:25)



So of course, asphalt is not used on its own, just like we do not use cement on its own. It is mixed with aggregate to give a good volumetric material and this material we otherwise call as asphalt concrete or bituminous concrete. Asphalt and aggregate together form asphalt concrete.

Now in cement concrete, a lot of our emphasis was on the fact that cement has to hydrate by reacting with water.

Not so in the case of asphalt concrete. Asphalt does not react with anything, it is simply coats the surface of the aggregate. And as the asphalt becomes more and more viscous, with the reduction in temperature, it makes a hard solid structure. Aggregate on the other hand forms a very important part of the load carrying ability of the asphalt concrete pavement. And because of that the gradation of the aggregate, the particle size of the aggregates is a lot more important when you consider asphalt pavements, as it is when you consider concrete pavements.

In concrete, the strength is mainly attributed by the hydration of the cement. The strength giving properties of the cement paste itself. Not so in the case of asphalt concrete pavement. So here the gradation of the aggregates is lot more important as compared to Portland cement concrete. So, the asphalt is not here to provide strength on its own. It does provide some strength because it becomes solid and very highly viscous at normal operating temperatures.

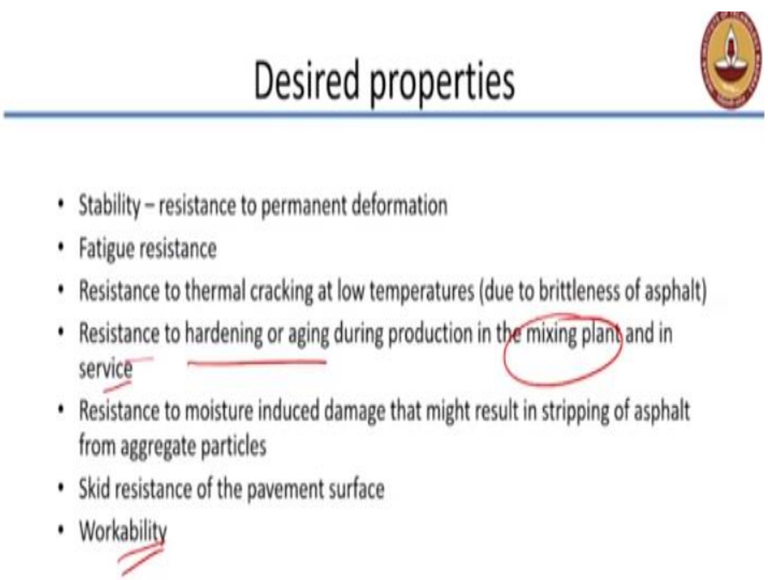
Nevertheless, its main function is to simply ensure that the aggregates are bound together nicely. And the strength and stability are more of a function of how well the aggregates are interlocked together. That is why I said gradation of aggregates is lot more important, when you consider pavements, as compared to when you consider buildings which are made with cement concretes.

(Refer Slide Time: 06:16)

Majority of the world's highways are with asphalt concrete. In fact in India, most of the golden quadrilateral highways are also with asphalt concrete. In the U.S 96% of the highways are asphalt concrete based highways**.** Now why do you think asphalt concrete is a material of choice for roadway pavements? 2 major aspects, one is the ease of construction and the speed of construction as compared to cement concrete pavements.

Asphalt concrete pavements can be constructed much faster as compared to regular cement concrete pavements, rigid pavements. Second is economy. Asphalt concrete is a lot cheaper as compared to cement concrete. You also have to think about longevity. Generally, cement concrete pavements are much more long lasting as compared to asphalt concrete. But you have to balance out all these issues before you decide which one you need to go for.

(Refer Slide Time: 07:11)



So what properties do we desire from asphalt concrete? We talked about cement concrete extensively previously. Similar to that what happens when we use asphalt concrete. As I said, this strength is not that much of consideration, it is more the stability. What is the resistance of this pavement material to permanent deformation? Especially because, asphalt is a viscous material, it will continue to flow under sustained loading.

So, what is the resistance of this material to permanent deformation? Other is Fatigue resistance, because we have highways that have loads that move continuously. It is not one static load. You have a load that is continuously dynamic, continuously getting replenished. So, you need to understand the number of cycles that the pavement material can undertake without collapsing. So that is called fatigue resistance.

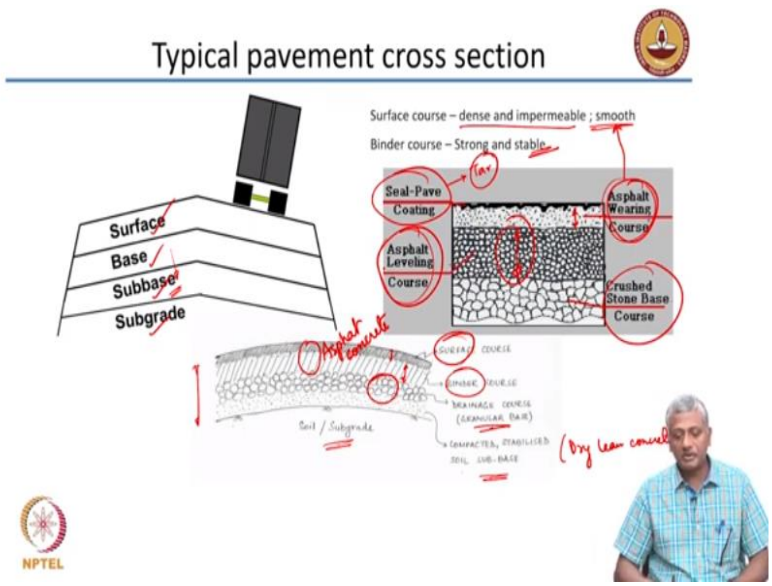
At low temperatures as I said polymers basically becomes brittle and starts cracking. And low temperature thermal cracking resistance is very important for the pavement. Now asphalt is a polymer which will be subjected to ultra violet radiations and also the effects of the heat during the mixing process and the formulation may also affect its properties and lead to a phenomenon which is otherwise called hardening or ageing.

When you have asphalt pavement that starts ageing because of the external exposure, they will start becoming less and less flexible, and then start cracking. Flexibility of the asphalt will reduce and because of that the resistance to hardening or ageing, not just in service but also in the mixing plant. Because that is where high temperatures are used to mix with the aggregate. And this high temperature leads to ageing of the asphalt much quicker.

You can also have resistance to moisture induced damages, one of the major parameters. Because when you might have seen, this is a common example. Whenever there is a heavy rain, on roadway structures that are not properly laid out, often time the aggregate, becomes loose and comes out. It basically strips off. The bond between asphalt and aggregate gets broken because of the rain because of the moisture. So, you want resistance against moisture related effects.

For ride-ability, you want to ensure that the pavement surface skid resistant. When your vehicle is travelling over it, it has to have a firm grip. And at the same time should not have such a large amount of friction that the material is not simply able to move easily. So we need to design your pavement surface for the right level of skid resistance. And the concrete mixture or the asphalt or bituminous concrete mixture has to be designed with a proper workability to ensure that you get a good spread and proper compaction of the material when you are making the roadway surfaces.

(Refer Slide Time: 09:55)



What is this pavement cross section? As I said flexible pavement is the system of layers that are acting together. And the load intensity keeps reducing as we come from the top layer to the subgrade. So, how is this happening? What are these layers? So, if you look at the simplest arrangement which is shown here. The bottom most layer is obviously the soil or subgrade. On top of which we are sometimes having a sub base which is a compacted and stabilized soil.

You may or may not have that, compacted and stabilized soil. If your bottom sub grade itself is properly compacted before placement, you do not need to have a sub grade layer which is compacted. Often times we do have that or sometimes even if we can have Dry lean concrete. On top of this, we have a drainage course or a granular base course.

As we said in the flexible pavements, a proper distribution of the load, as well as the drainage of any moisture that gets into the pavements is made possible by the use of these layers which has the granular materials that are simply compacted together. There is no cementing agent inside. On top of this, you basically have the asphalt concrete. So this entire thing is the asphalt concrete. So there are several ways of calling these layers of asphalt concrete. Usually there are 2 layers.

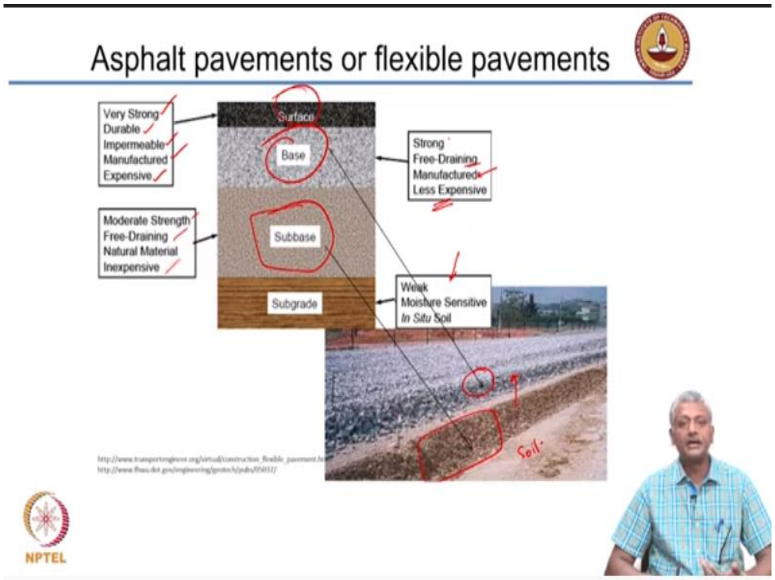
The lower layer or the thicker layer is called the binder course. The top layer, thinner layer is called the surface course. There is another way of calling it. You have the asphalt leveling course which is the thicker layer and you have the asphalt wearing course which is the thinner layer on the top. That is another way of calling the surface course and the binder course. As I said crushed stone base is the same as here.

Again, same thing here sub grade, sub base, base and then surface sub means below. So, subgrade means below soil, below ground level. Above ground level you have sub base because it is below the base. And base basically it forms the base for the concrete pavement on the top. So this is the layer wise distribution of a flexible pavement made with asphalt concrete. So we have touched, you have subgrade, sub base, granular base, binder course or asphalt leveling course and surface course or asphalt wearing course on the top.

And as I said earlier, sometimes we need to protect the surface from the spills of petrol and gasoline, diesel that you may get which may dissolve away the asphalt. So, you have a seal coating on the top surface which made with materials like tar which can form a smooth layer on the surface without causing any dissolution of the asphalt underneath. So, the surface course or the asphalt wearing course has to be dense and impermeable obviously, it should not allow any moisture to penetrate.

It should also be smooth enough to allow a good ride on the surface for the vehicles. It has to allow a good ride for the vehicles so it should be smooth enough. The binder course on the other hand or the asphalt leveling course has to be strong and stable because it forms the majority of the asphalt concrete thickness. So that is what leads to the stability of the entire structure. So very important to understand these layered materials is to how they are distributed across the pavement

(Refer Slide Time: 13:33)



Again a picture-based scenario is depicted here. So, as I said you have the soil here. This is the soil, on top of the soil, you have the sub base. The soil itself may be weak and moisture sensitive or it may be strong, we do not know. You have to determine the quality of the soil first before you decide on the number of layers and thickness of each layer that is required. So that is all part of pavement design which you learn later in your high way material course.

Sub base itself has a moderate strength, free draining, that means the water can get out of it. It is usually made with natural materials as I said with sand or soil and its inexpensive. As you go up to the next layer, this becomes the base course. The base course is strong, because it is got granular materials which are compacted together. And then you have free draining quality because of which it is able to bring out water.

It is manufactured, because you have to place it and then compact it on top and then it is less expensive, obviously as compared to the top layer which is the asphalt concrete pavement. It is very strong as compared to the bottom layers, durable, it is impermeable. It should not allow water to penetrate. It is manufactured obviously the materials are mixed together, properly laid and then compacted and finished and obviously for all these reasons, it is going to be expensive. So this is a structure of a typical flexible pavement.

(Refer Slide Time: 15:11)

Laying of asphalt concrete

What is been shown here is the laying of the asphalt concrete. So, you have this instrument which is called paver. This is a paver truck, basically. So, what it does is it has this hopper which carries the asphalt concrete inside. If you are mixing it at asphalt concrete centralized plant, so you need this paver to actually bring that materials to the job site. So, you mix it somewhere and bring the material.

This container in which the asphalt concrete is kept basically tilts to discharge the asphalt concrete. And the asphalt concrete gets discharged into this paver. That is the paver and this is actually the truck which has a tilting back and discharges the material into the paver. So, this is your paver. So, what the paver does is takes the material and passes it through almost a set of plates that will ensure that you get uniform thickness of the pavement that is laid out on the road surface.

So, you see, how nicely it is been laying out, this material on the road surface. So, paver is able to lay out uniform thickness or strip of the asphalt pavements on the road surface. And then you obviously you will have, the next step will be that this road surface will have to be compacted using a roller.

(Refer Slide Time: 16:37)

Again, I will show you that. Here you have the truck which has a tilting back which discharges the material into this paver. The paver is rolling out a thin strip and the roller is compacting, the pavement in that direction. This is the mechanized way of constructing roadway pavement. Again, another picture of the truck with more clarity where you can see the tilting back basically which is discharging the material and there we have the paver on this side.

Now sometimes these pavers are also accompanied by finishing tools like this. So, this is the edging tool so you are making a good edge for the pavement. This is the edging tool and this is the close up of the pavement surface. So that is the close up of the pavement surface. As you can see, in the close up it looks very rough. But actual ride ability is quite good. But when you take a picture from a very close on top of the pavement, you are able to see obviously the structure of the entire bituminous concrete.

So, you see some air gaps, you see some aggregates and so on. You do not see a perfectly black layer on the top comparing to the picture that you see here. Because you are taking the picture far away from the road surface, you do not see the kind of features that you would see right up close at the surface.