Basic Construction Materials
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Module No # 09
Lecture No # 45
Pavement Materials 1 – Part 1

Hello everybody and welcome to the last segment of this course on basic construction materials and this is going to be on pavement materials. Till now we talked about all the materials that are used in buildings. And let us now move out of the building to the roads which are a very important part of our construction process. As I said in the beginning of this course, this course has not really touched upon soil as a construction material because that you will have a very vast coverage of, when you start your studies in geotechnical engineering.

However as I said before, soil is very important from the point of view of performance of lot of difference types of structures because it forms the basis of the foundation design. Here in pavements, the soil also functions more than just the foundation. It sometimes forms layers of the pavement itself and that is something we will take a look at as we go along in this chapter. So this chapter is about pavement materials or roadway materials or highway materials.

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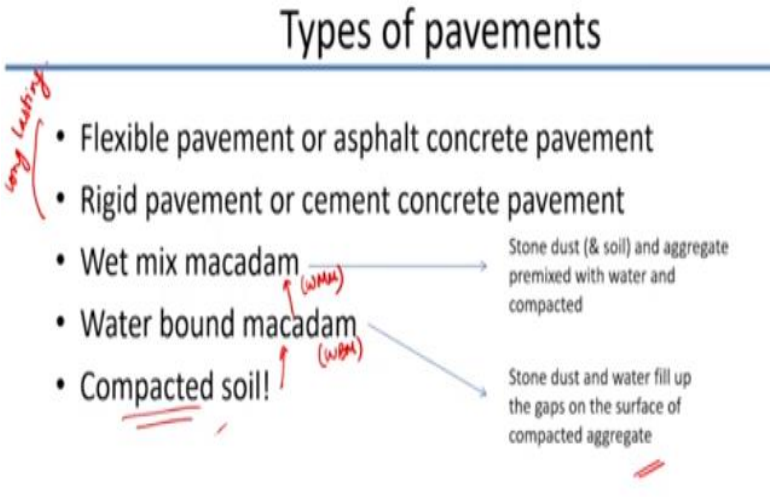

So what are the different types of pavements that you come across? The simplest one obviously is a compacted soil. You just have a rough soil, you have a roller going over the soil compacting

it and making sure that its smooth and plane and that can be used as the pavement or a road you then go to slightly more complicated version called water bound macadam. What is water bound macadam?

It is basically stone dust and water that filling up the gaps on the surface of compacted aggregate. So you have the soil on top of which you place aggregates, that is stone and then you take a roller and compact this aggregate. So what happens is, the aggregates nicely get compacted and come close to each other. But then there are still gaps around, so what you do is you mix stone dust and water make slurry and fill up these holes.

Again this is not that complicated but it is a little bit more complicated that just compacting the soil. From here we move to a slightly more advanced approach called the wet mix macadam. So here, instead of compacting the aggregate and then putting the soil slurry inside or stone dust slurry inside, what we do is we mix up stone dust, some sand and soil and the aggregates along with water in a mixture. Then we pour it out on the surface and then compact it.

So you have the water bound macadam giving rise to a higher level of road way construction that is wet mix macadam. So this is also called WBM and this is called WMM-wet mix macadam. So these are all quick and easy ways of doing pavements. But if you really want a long lasting pavement you need to select between these 2 options. So these are the long lasting options that you have - either flexible pavements which are made with asphalt concrete or bituminous concrete.

On the other scale you have rigid pavement or concrete pavements that are made with cement concrete that means cement is used as the binding agent. In the previous case, you have asphalt user the binding agent. Of course about cement we have learnt a lot in the chapter on cement and concrete. Here we will talk a lot more about asphalt and then we will compare different types of pavements and their applications.

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So I am showing you some pictures here of the use of wet mix macadam. So you see the macadam being poured out on to the roadway surface and then it is going to be compacted. Now below that of course you have a layer of just your stone base. Again this is a plant at which you are producing this wet mix macadam. You have stone, stone dust and may be some soil also. This will be batched just like we do batching of materials in concrete and then they will be mixed together.

And then transported to the site for placement and then they will be compacted using a roller. So this is a roller that is essentially compacting the surface. And the road almost looks like a normal road except that it is not going to be of high strength because there is no binding agent. That is keeping the aggregates together, so to think about the binding agent we have to move towards either cement or bitumen.

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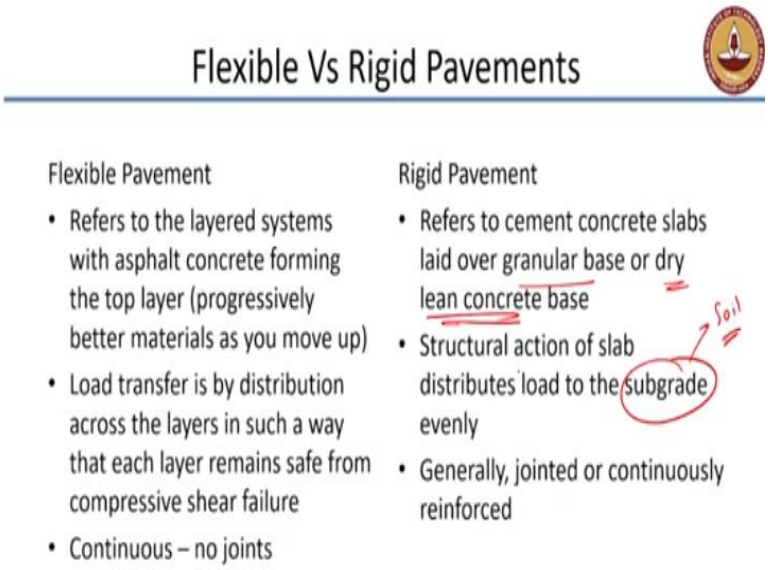

So now let us look at the difference between the 2 major types of long lasting or high strength durable pavements. These are flexible pavements in one hand and rigid pavements on the other hand. So, flexible pavement essentially refers to the layered systems with asphalt concrete forming the top layer. We will take a look at this cross section of the layers a little bit later in this chapter. So asphalt concrete or bituminous concrete forms the top layer and then it is got subsequently several other layers also.

So as you go up from the soil surface to the top of the asphalt concrete you are consistently improving the kind of materials that are being used. The load transfer, so you have a vehicle moving over this pavement, the load transfer from the wheels of the vehicle happens in such a way that we distribute it across the layers and each layer basically remains safe from compression or compression related failure like shear failure for instance.

So what would that mean? We have a very good quality material at the top so it can take larger load intensity. But when it transfers this load to the layer below, the intensity has to reduce and then further reduce and further reduce. That is what the idea of flexible pavement is that it is able to deform the layers are able to deform in reduce the load in intensity in such a way that what you convey to the bottom layers is lower than what the top layer feels.

So load transfer is where distribution across layers in such a way that each layer remains safe from compressive shears failure. So that is a flexible pavement. Why is it called flexible?

Because the layers are free to deform, free to move. And this deformation reduces the load density. A flexible pavement does not have joints, it is continuous. A rigid pavement basically refers to cement concrete slabs.

We talked about different types of concrete structures like columns or concrete elements like columns, beams, slabs. This is just slabs that is been placed on the ground. Now it is not just placed directly on the ground but we have usually a stone layer, granular base we call it or we have a dry lean concrete base that means something which has very less cement almost like fully aggregate.

We prepare a base level layer on top of the soil and then put the slab of concrete on top. Now the slab itself is quite rigid. It does not deform freely, so the slab itself will have a structural action that will bear the loads that is why we do not call it flexible anymore, we call it a rigid pavement. The structural action of the slab basically distributes the load to the surface-subgrade.

Again I have introduced a term here subgrade. Subgrade is nothing but the soil underneath, this is called the subgrade. Now in road way terminology or in transportation engineering terminology, grade means which is at level with the soil or at level with the earth surface is called grade. Anything above grade is called above grade and anything below grade is called sub grade so soil is basically a subgrade material.

So the slab, itself have the structural action, it basically bends and takes the compression and tension and so on and transfers this load evenly to the subgrade. Generally concrete pavements will either need to be jointed that means you do not have a continuous strip of concrete, you need to break it up into small joints or small slabs which have joints between each other. Or you have continuous strip which is reinforced continuously because again you need to reinforce it if it has to take care of tension.

So that is the essential difference between flexible and rigid pavement and this is something that you will start off with in your highway materials course or highway engineering course again later in your higher semesters.

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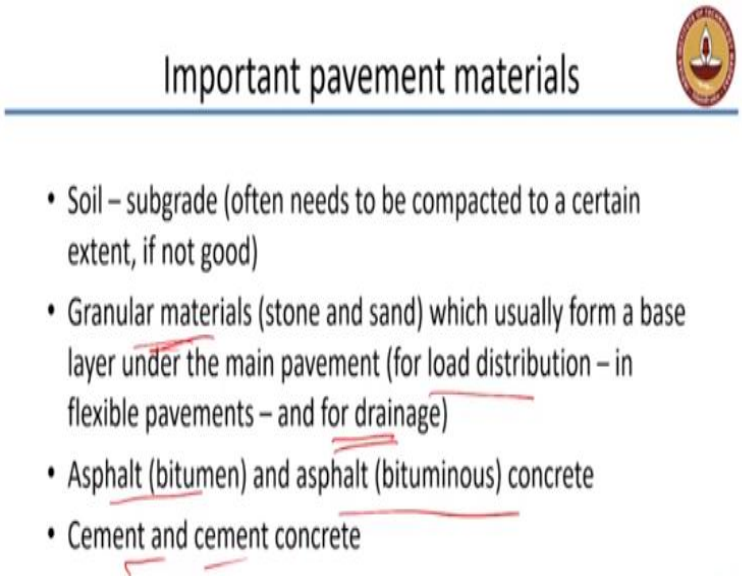

So what are the important pavement materials? As I said soil or subgrade is the bottom most layer. It often needs to be compacted to a certain extent if the soil is too loose, you cannot really build a road on top of it. It has to be compacted to make sure that it has some level of stiffness on which the road can sit in an even fashion. Very often we choose granular materials, just stone, sand, coarse sand for instance.

They form a layer over the soil on which your entire pavement slab either made of bituminous concrete or cement concrete can rest. And the provision of this granular material is useful not just for load distribution which mainly happens in flexible pavements, but also for drainage. If any water enters the pavement, it has a change to get out from this layer which is made with granular materials.

Because it is got a lot of gaps inside so it will let out the water and drain the pavement quite easily. And of course when we go to the top surface, it is either made with bitumen and bituminous concrete or cement and cement concrete. Of course, just like you do not construct anything with just plain cement. You do not construct anything with just plain asphalt, it has to be either cement concrete or asphalt concrete.

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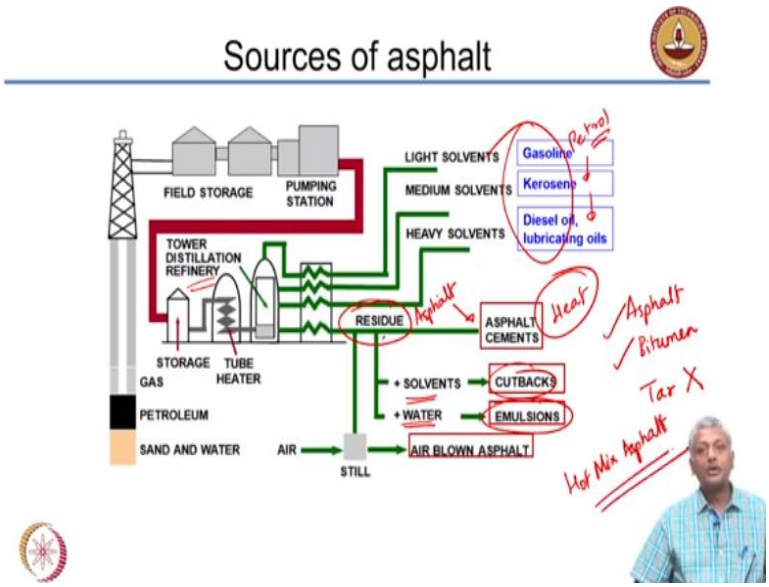

So now we have to understand what is asphalt? How it is made? And what are its properties? We talked about cement extensively before so I am not going to touch up on the same thing here, cement concrete for a building same as cement concrete for a pavement. It is designed and produced in the same way. So let us talk a little bit about asphalt concrete. Where is asphalt obtained or bitumen obtained?

Asphalt and bitumen are one and the same. So again many of you may have different terminologies- asphalt, bitumen and some of you may even call such pavements as Tar roads. That is wrong. It has to be either asphalt or bitumen; tar is incorrect because tar is a different material. I will touch up on that just a minute. So bitumen or asphalt is obtained during your fractional distillation of crude oil.

So you take crude oil and then you are sending it through your distillery or refinery and then you make all kind of products from it. You get light solvents like gasoline or petrol. They are basically light solvents and then you get medium solvent like kerosene and then you go towards heavier solvents like diesel oil and lubricating oil. So, all your transportation necessities are all coming from the fractional distillation of crude oil.

And lot of energy necessities like kerosene and diesel oil and all that are coming also from your distillation of crude oil. This probably one of those most important events that may happened in human history is people learnt how to actually do a fractional distillation of petroleum to obtain

all these products. All of which form a significant part of the lives today. But as you further and further you get the residue, after you extract all the interesting things out you get the residue which typically oil companies do not really have much use for.

But later they realize that these civil engineers need this material. This residue basically forms the asphalt or the bitumen and we need it in very large quantities, tons and tons of it is needed to make roadway pavements all across the world. So because of that even though this material actually is a residue from the point of view of the oil companies, it still gets sold for very high prices, especially if it is a good quality.

So the residue basically is called asphalt or it is also called asphalt cement. Now on its own the residue itself is not easy to use, it is very viscous and you cannot use it. So to make it less viscous you have to adopt different types of strategies. You either heat it up to reduce the viscosity or you dissolve it in a solvent which is called a cut back or you suspend it in water and make an emulsion out of it.

And that is something you are quite familiar with, especially with respect to paints; you sometimes get these emulsion paints where paint droplets are basically suspended in a liquid medium with water. And you have some dispersing agents that ensure that the paint does not agglomerate inside. When you put the paint on the surface of the structure, the water evaporates and the paint remains behind. That is the same concept with asphalt emulsion also.

A cut back on the other hand means asphalt is dissolved in an organic solvent. What solvents will dissolve asphalt? All these solvents will dissolve asphalt-gasoline, kerosene, and diesel and so on. So you dissolve it in that solvent and mix it with that aggregate and lay it on the road and compact it the solvent will volatilize and the asphalt will remain behind. So that is the concept of using ways to reduce the viscosity of the asphalt.

But the most common strategy is to heat the asphalt and that is what you see in most of our roadway construction is with hot mix asphalt. That is what we call it as hot mix asphalt or warm or hot bitumen.

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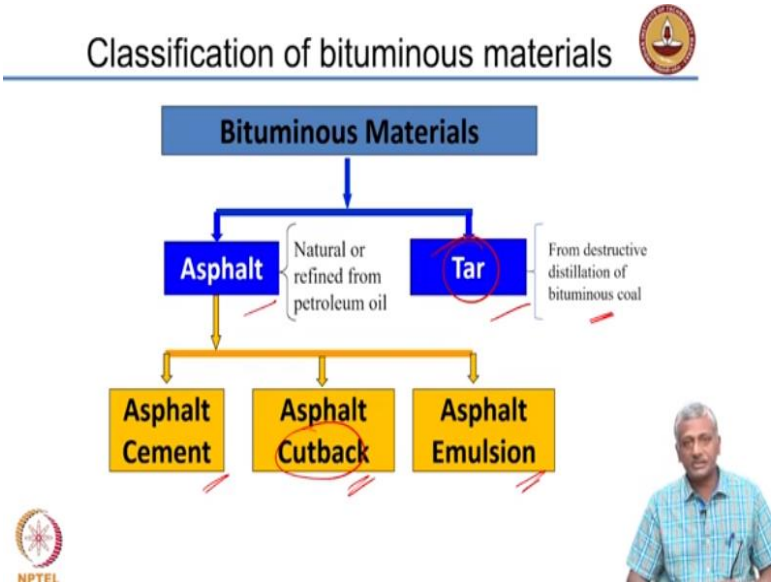

So again just to come back to the same thing, your bituminous materials are typically divided into either asphalt or tar. And as I said tar is not the same material, tar is a different material. It is obtained from destructive distillation of bituminous coal. It is not obtained from fractional distillation of crude oil. Please make sure you understand that and that leads it have a very special property which will talk about just a minute.

So asphalt basically can be asphalt cement where it is heated up and then it serves to reduce the viscosity and leads to a proper mixing with the aggregates and forms the pavement surface or it can be a cut back where it is immersed or dissolved in an organic solvent. Emulsion is when, it is suspended in water. So these are the ways in which you can use asphalt or bituminous materials. Now I said that in a cut back the asphalt is getting dissolved in an organic solvent.

So now imagine you have a roadway surface which is made with asphalt concrete. And you have a vehicle from which petrol is leaking, what will happen? If petrol leaks, petrol is an organic solvent in the same process of fractional distillation and that petrol will start dissolving out some of the asphalt. And that may not be a good thing for your road surface. So you want to actually give a treatment on the road surface with the material that will not get dissolved by the organic solvent.

And what material would that be? In this case of course, we can use tar as a sealing layer on the surface that protects the road surface from getting damaged by the action of organic solvents. We

will touch upon that later also. So, again as I said asphalt is from either natural source, I told you about this in the introductory chapter I was talking about the use of natural pools of asphalt.

And taking asphalt and using it as a binding material for masonry or it is refined from petroleum oil refinement basically the fractional distillation of crude oil.

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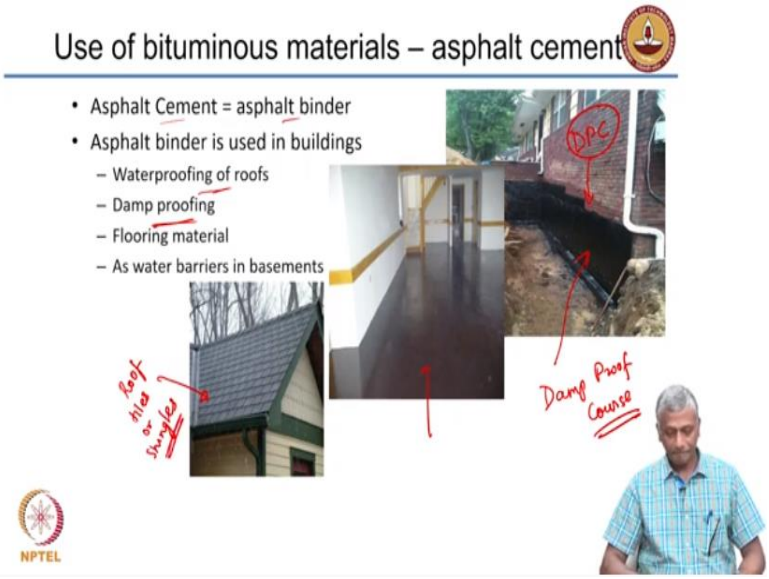

So, where are these bituminous materials used apart from of course roadway pavements? That is something we will talk about extensively but where else do we use it? Asphalt cement is nothing but asphalt binder and this is something which is used significantly in buildings mainly for water proofing purposes. Where are we using it? We use it in water proofing of roofs. We put it as a surface layer on top of the roofs usually mixed with other ingredients, we are not covering water proofing materials here, but essentially it is used there.

This is actually an asphalt layer which is getting struck to the building in such a way that water from the ground does not rise into the building. So this is called a DPC or a damp proof course. Especially with masonry it is very important to provide a damp proof course to ensure that the water from the soil does not enter the masonry structure. So that is called damp proofing. Often times asphalt is a good flooring material.

And sometimes in basements it can be used as water barriers just like what is shown here. So because of its water repelling properties, it is a good part of water proofing solutions. So apart

from roadway pavements and buildings you will asphalt typically used in such purposes and here of course there is also an example of the use of roof tiles or they are also called shingles.

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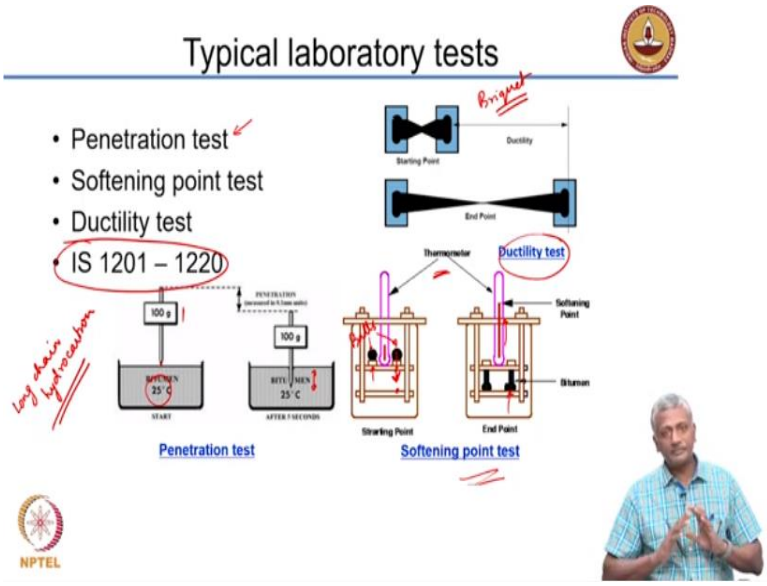

So now when you obtain asphalt, you have to test its properties just like we talked about cement. Cement has very interesting properties; they need to be tested in the lab. Just like that asphalt also needs to be tested. And asphalt forms one of the polymeric materials that we know of in construction. Asphalt is nothing but a polymer. Asphalt is a long chain hydrocarbon, so you need to be able to understand what is the degree of polymerization?

What are the effects of the effects of that on the overall properties of the asphalt and so on, so I already told you that the primary aspect about asphalt cement is that it has very high viscosity and cannot be used as such. So it needs to be heated up or to needs to be dissolved in an organic solvent or it needs to be suspended in water. So obviously a lot of testing revolves around the strategies for reduction of viscosity and therefore we have to obviously test the viscosity of the material itself.

Now this can be tested in several ways. One is called the penetration test. As the name indicates it has a mass of 100 grams attached to a needle which is on the bitumen surface at 25 degree Celsius. And then you measure the depth up to which this needle penetrates under this mass of 100 grams. That is called the penetration depth. And the quality of the asphalt is sometimes graded as per the depth of penetration in this test.

Again asphalt is highly ductile. It can stretch quite a bit before it breaks and that ductility is tested by making a briquette of the asphalt and then simply stretching it in a controlled temperature condition. Remember in the chapter on polymer and composites, I talked about the fact that whenever you are testing polymers the temperature has to be kept constant and the rate of loading has to be very clearly defined.

So same thing applies in the case of asphalt also, the temperature and rate of loading have to be perfectly maintained when you are doing tests on the asphalt. And then you have the softening point test. Here what we are doing is we have the asphalts sitting inside these 2 small cylindrical containers. So almost like a film of asphalt, on top of which we put these steel balls we put these steel balls on the top and then we increase the temperature.

The thermometer is there to measure the temperature. We increase the temperature of this entire setup. As the temperature goes up the asphalt starts softening, it starts reducing its viscosity. So what will happen as a result of that this ball will come through the asphalt layer because asphalt softens the ball and this will start coming through the asphalt layer and ultimately it touches the bottom plate.

The temperature at which this ball just touches the bottom plate, the ball and the surrounding asphalt together touch the bottom plate that is called the softening point. Apart from this we also need to test obviously the viscosity of the asphalt. There are different ways of doing that, I am not going to get into this. The primary test on asphalt are covered in this IS standard, Bureau of Indian standard 1201 to 1220. There are several standards ranging from 1201 to 1220 where they are covering the basic test methods on asphalt.

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Now sometimes when asphalt concrete is functioning in the pavement, you can imagine that the kind of effort that it takes to compact the asphalt concrete and pavement is quite different from what can be done in the laboratory. In the pavement, in the actual field, you have a roller which is compacting the road surface. So the degree of compaction you achieve using the roller in the real life is not easy to simulate in the lab.

In the lab what will you do? You will mix up your asphalt concrete, you put it in the cylindrical container and then start compacting it some way or the other. You can use different methods of compaction, I am not going to cover that here. That is going to be part of a higher semester course for even highway materials. But what I am trying to say is, the compaction energy of the real life pavement construction example can never be properly simulated in the laboratory.

So because of that sometimes we have to actually take samples from the pavement itself and do tests on that. So here for example there is a coring bit. This is actually a core bit which is drilling a hole into the pavement and bringing out these cores. So from this hole you get these cores out, cores of bituminous concrete. Again this coring operation is being shown here. This core bit is electrically controlled and it has a very high speed revolving cylindrical bit which has a diamond tip which is basically cut through the material and extracts the core out.

And this core is then brought back to the lab and tested under control conditions for strength and stability basically which is the resident deformation. And sometimes you also want to study how

much voids are there in this structure. So with the advent of new technology, it is now become possible to start simulating this kind of a roadway pavement construction technology or methodology in the laboratory by the use of a technique which involves an instrument called the gyratory compactor.

Gyratory compactor basically compact the asphalt and applies this gyration which is usually there when you actually have the effect of the roller on top of the pavement surface. So this (24:34) compactor today in modern labs has become a very useful instrument to produce concrete asphalt concrete in the lab without really having to depend on samples from the field.