Course Name – Pavement Construction Technology
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A very warm welcome to all of you for today's lecture. I am Rajan Chaudhary, a professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati, and an instructor for the NPTEL MOOC course on Payment Construction and Technology funded by the Ministry of Education, Government of India. This particular lecture will form part of lecture eight, which is on the characterization of bituminous-bound materials under module three of the course. At the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches. Now, when we talk about bituminous-bound courses, the term "bitumen" automatically comes to mind. Now this bituminous-bound mix will have a combination of bitumen and aggregates; these are the two major components, and there may be other classes if we are adding some additives to it.

So, we can basically classify the bituminous courses of flexible pavements and the composition of bituminous mixes into three individual constituents. One will be your bituminous binder, the one that is going to bind your aggregates, which again fall under different categories of coarse, fine, and filler. Along with it, there may be certain additives that may be used to impart some specific characteristics. But the two main components will be your bituminous binder and aggregate.

Now, how do we produce it? These bituminous mixes are produced at a hot mix plant. Most of the bituminous mixes are produced at a hot mix plant. Certain small works may involve on-site preparation of specific categories of bituminous mixes. Otherwise, a hot mix plant is always preferred, and we call it a hot mix plant because the production is at higher, elevated temperatures. So, bituminous mixes are mainly produced through a hot mix plant of adequate capacity; it depends on the quantity of production you require per hour, and is capable of producing a mix of proper and uniform quality.

This is important because there is a control here with respect to the uniformity of the mix in terms of aggregates and binder, in terms of the temperature at which the mix is produced, so as to have thoroughly coated aggregates; this is what the purpose is. Now, when it comes to bitumen, when we are looking into the characterization of individual materials of bituminous bound courses, as in the previous lecture, we looked into the characterization of aggregates when we were discussing the unbound courses, certain classifications of aggregates remain the same; only the requirement of individual values of particular characteristics will differ when you are using them in granular courses or when you are using them in bituminous bound courses. In this lecture, we will first start our discussion on the characterization of the major material, which is the bituminous binder. Now this bituminous binder is known by different names; it is known as bitumen. We can call it a bituminous binder and also an asphalt binder.

So what it looks like is a dark, viscous material ranging from solid to semi-solid or liquid form. So its consistency changes with a change in temperature; this is what a thermoplastic material is: its consistency or fluidity changes with a change in temperature. And so it is a dark brown viscous material ranging from solid to semi-solid or liquid form with strong adhesive and waterproofing properties. This is a very important characteristic of this material. And from where do we get this bitumen? We get it from the refining of petroleum crude; this is the major source.

When the refining process of petroleum crude started with the growth of automobiles, a lot of bitumen was also produced, and the use of this bitumen, which is derived from the refining of petroleum crude, became very popular. In addition to this, it also occurs naturally; there are certain sources and certain lakes where natural asphalt is also found. But once this refining of crude petroleum came into the picture, the quantity and quality of the bitumen derived from it were very good, and therefore it became more popular compared to natural asphalt. And this material is completely soluble in toluene and trichloroethylene. This is a definition as per IS334.

Now, under this bituminous binder, there are normally four different categories that are popular specifically for bituminous pavement construction or flexible pavements. The first one is paving bitumen, the most common and widely accepted type of bitumen. The second, if I modify certain characteristics of this paving bitumen, it can come under the category of modified bitumen. The modification can be done in different manners; it can be through some additives of polymers, such as waste materials like waste plastic and waste rubber, along with some synthetic polymers, elastomers, and plastomers when added. It falls under the category of modified bitumen.

Then there are two other categories, namely cutback bitumen and emulsified bitumen. One application of this particular method is when you want to produce the mixes at ambient temperature. So you do not need to heat your binder. So then you go with the cutback bitumen and emulsified bitumens. So, the one that is most popular and widely used is the paving bitumen, and this is what we are going to look into for the characterization.

The choice of bituminous binder is to be clearly stated in the contract or by the engineers. Whenever a project is to be undertaken, it has to clearly define what type of binder is to be used. Now, as I mentioned, there are various IS specifications and IRC specifications. This is BIS specification 73, paving bitumen specification; this is SP53 on the use of modified bitumen, IS15462, again polymer-modified bitumen specification, IS217, cutback bitumen, IS8887, bitumen emulsion, and IS17079, which is rubber-modified bitumen. So, we have different specifications available from BIS, as well as MoRTH and IRC, to refer to for these different types of binders.

Now, why is this bituminous binder so popular in road construction? It is popular because of its inherent characteristics. One of the inherent characteristics is its excellent binding properties with most of the aggregates. It sticks nicely with most of the aggregates you can see. So, this is the sticky nature, which is present in most of the aggregate types that we have. So that's a wonderful character.

The second is the waterproofing characteristics. It is a water-repellent material. You might have heard that bitumen is used as waterproofing in various industrial applications. This is one picture. It's a very old picture.

It shows a 75-centimeter-long boat made of bitumen mixed with earth dating to the Akkadian period in Mesopotamia around 2300 BC, because the waterproofing nature of bitumen was known at that time, even though this bitumen was also used in mummification. So, these characteristics of bitumen are very important, which made its use widely popular in the construction of roads. Another part is that since it is earlier, it was extracted as a sort of residual during the refining of crude petroleum. So, it was relatively low cost as well, but with the gain in popularity and the increased demand for bitumen, the price is rising. Now, we have asphalt binder; this is another term used for bituminous binder, which is dark brown to black in color and is either naturally occurring or produced by petroleum crude refining.

So, you can see this is a natural lake where natural asphalt is coming up from well beneath the earth's surface due to the pressure; there are certain lakes, such as Trinidad Lake, where this is also being produced. This is that example; this is Trinidad Lake, where you can see they are producing it. Now, there is a lot of composition in this particular one; there will be a share of the bitumen also, and some volcanic ash will also be produced. So, this was used earlier, before the refining process became popular. After that particular one, because of the good quality and the abundant quantity that was available through crude refining.

This became less popular, and there are certain natural sources of natural asphalt as well, such as Trinidad Lake on the island of Trinidad, Bermudez Lake in Venezuela, and certain sands in western Canada where a good deposit of natural asphalt is also found. And as I said later on, with the specific requirement for the growth of automobile fuel, the refining of petroleum crude took place in the early 1900s. The bitumen, which is derived from the refining of crude petroleum, became more popular. So this is obtained by separating out the different fractions of petroleum crude; you can see this is a distillation chamber, and different fractions are separated out at different levels. So, the one which is obtained in this particular one at the lowest is the residuum, which is your bitumen.

Now, this is the residual bitumen fraction which is obtained during the process, and this is also further refined or processed to get the desired quality of bitumen. There are various ways of further processing: degassing, air blowing, and vacuum application. So, in order to derive or achieve a composition of bitumen that is suitable for our road construction. Now, when you have this bitumen, which is derived from the refining of crude, you need to get it from different sources; we have a good number of refineries in India, with more than ten refineries available. They use some of the crude that is being produced in our country, and a good amount of crude is also imported from other countries.

Now that we have this bitumen obtained from these different refineries, we need to compare the bitumen to ensure its quality. Certain parameters must be ensured for the bitumen to judge its suitability in road construction. So under this particular one, we have a few divisions to ensure the quality or the suitability of a bitumen for our road construction purposes. There is one category that falls under the consistency test, the second category is under the aging test, the third is the purity test, the fourth is the safety test, and there are a few other tests that are also advised while judging the suitability of bitumen for road construction. We will discuss them one by one.

Now, first comes the consistency of the bitumen. As I mentioned at the beginning, bitumen is a thermoplastic material; its consistency varies with changes in temperature. So, at lower temperatures, it will be a solid or a semi-solid; when I increase the temperature, it starts flowing, so it changes from a semi-solid to a liquid state. So, now, if I want to compare bitumen from two different sources, that means I have to compare them at the same temperature; specifically, that is the important thing: the same temperature and the same shear loading conditions also. So, to determine the consistency, which describes the degree of fluidity of bitumen at any particular temperature, is important.

So, temperature is important when I need to make a comparison of different bituminous binders. If I have binder from four different sources, I will check which one is the best or which one falls within my requirements, and I will pick it. So, for that particular one, one category of evaluation is the evaluation of the consistency of the binder, which is very important. It is necessary to measure its consistency at the same temperature and shear loading conditions. Now, how do we ensure the fluidity or consistency of binders so that we can compare different sources? There are four tests that are widely used.

One is the absolute viscosity measurement done at 60 degrees centigrade. Second is the kinematic viscosity measurement done at 135 degrees centigrade. The other test is a penetration test done at 25 degrees centigrade, and the fourth one is the softening point test. These are four widely preferred tests for determining the consistency of bitumen. Now, what is done under the absolute viscosity determination? As we know, viscosity is a fluid's resistance to flow.

So, we want to get an idea of the viscosity of the binder that we are going to use. Now, this is expressed as the ratio of the applied shear stress to the resulting rate of shear strain. So, this is what your coefficient of viscosity is. So, when we talk about the coefficient of viscosity, it is your tau divided by your shear rate. So, this is your coefficient of viscosity.

Now, this coefficient is a measure of the resistance to the flow of the liquid and is commonly known as viscosity. So, we need to see what the viscosity is in order to get an idea about the fluidity of the binder at a particular temperature. And another aspect that is important with respect to bitumen is that you might have read in physics that there are two types of liquids: one is Newtonian liquids, and the other category is non-Newtonian liquids. Bitumen behaves both as a Newtonian and a non-Newtonian fluid, specifically at temperatures lower than 100. It behaves like a non-Newtonian fluid; what is that? The relationship between shear stress and shear strain rate is non-linear.

So, you do not have a constant viscosity; that is why you have to define the temperature and the shear loading conditions to measure your absolute viscosity at a particular temperature. So, the temperature that is recommended is 60 degrees centigrade. So, for this particular one, the code referred to is IS1206 part 2, 2020 version, which is the 2022 version, and it mentions three types of vacuum capillary viscometers. One is Cannon Manning, which is the most widely used asphalt institute vacuum capillary viscometer and modified copper vacuum capillary viscometer. So, three types of capillary viscometers are shown in these pictures, which are used to measure the viscosity of your bitumen.

What is done specifically is that I will explain what is done in this viscosity measurement: we conduct this viscosity measurement at 60 degrees centigrade because this is considered the maximum temperature that can be expected in a bituminous pavement after its construction. So, this is because it approximates the maximum HMA pavement surface temperature in summer. So that is why 60 degrees was the temperature that was fixed. And Cannon Manning vacuum viscometer, as I said, is the most widely used capillary viscometer for the determination of absolute viscosity. So, you can see this is a smaller mouth, this is a bigger mouth, and this is a Cannon-Manning capillary viscometer tube.

You will pour the bitumen into the wider mouth, and once it is poured, you can see this is the mark, which you have; once it is poured, thereafter, you will apply a standard vacuum on the other end. So, it says the bitumen is heated to a maximum of 90 degrees until it becomes pourable, and then you need to pour it. And you need to apply a vacuum of 30 centimeters of mercury so that you can apply a standard shear loading condition to this particular one while this capillary viscometer is in the water bath, ensuring that the water bath maintains a temperature of 60 degrees centigrade. So, this is done by keeping this capillary viscometer in a water bath to attain a 60-degree temperature. Now, how do you measure the time taken for the bitumen to pass from one mark to the other? So, for different capillary viscometer tubes, there are calibration coefficients and constants.

So, they now give what you record in this particular one; you record the time taken from one mark to the other, the bitumen it takes from moving from one mark to the other mark. So, what we do is record the flow time for the bitumen meniscus to pass between the timing marks, and from there, you get your viscosity in poise, where K is your calibration constant and t is your flow time. This calibration constant is provided by the manufacturer of this particular tube. So, this is to be given by the, so there may be different calibration constants for different types of tubes and even for those supplied by different manufacturers. So, this gives you an idea of the consistency of the binder at 60 degrees centigrade, which is the temperature at which these bituminous mixes have to perform in the field.

Second is the viscosity that we require at elevated temperatures, and for that, we go for the kinematic viscosity measurement at 135 degrees centigrade. Now, for this particular one, this is a temperature that represents temperatures close to your production temperatures. So at these temperatures, the binder behaves like a bituminous binder; most of the bituminous binders behave as Newtonian fluids. So that means their shear stress is proportional to their shear rate. So, you have now, in this particular one, again, the standard viscometer tubes which are used; the one which is widely used is Cannon Fenske's opaque viscometer tube.

Now, again, here you pour the bitumen in one end, and you will have this particular bath, which is there to control your temperature. Now, here you are going to maintain a temperature of 135 degrees centigrade, and then these tubes are kept in this particular bath. Here again, the binder is inserted in this particular one, and you need to ensure that at this particular consistency and temperature, the binder moves under the gravity itself. So it says the kinematic viscosity of a Newtonian fluid, which is a binder that behaves as a Newtonian fluid at this particular temperature, is the ratio of the viscosity to the density of the fluid. It is a measurement of resistance to a fluid under gravity because at this temperature, there is no requirement for a vacuum to be applied.

So initially, a small partial vacuum may be applied once to start this movement, and thereafter it moves under gravity. So then again, these timing marks are there, and you need to note down the time it takes to move from one timing mark to the other, and thereafter, the kinematic viscosity at 135 degrees centigrade in terms of the units of centistokes is given as the calibration constant of the viscometer, and the other is the efflux times to move from one timing mark to the other. So, these are empirical measurements specifically of your consistency; through indirect measurement, you are getting an idea about the consistency via the viscosity measurement at 60 degrees centigrade and through the viscosity measurement at 135 degrees centigrade. And the 60 degrees is giving an idea of how the viscosity of the binder will behave during its service life at maximum temperature, while 135 degrees gives you an idea of how the binder will perform during production, as it has to coat the aggregates in a uniform manner. Now, another test that is quite common for measuring the consistency or fluidity of a binder is the penetration test.

Now it is an empirical test that is widely used to measure the consistency of bitumen. Now that it is done, this particular test is conducted at a temperature of 25 degrees centigrade, which is normally considered the ambient or the most approximate average service temperature because there may also be lower temperatures and maximum temperatures; thus, 25 degrees centigrade for most regions is considered the approximate average service temperature during the year. And this is a simple test where a binder sample is taken, then a needle assembly is taken, and it is allowed to penetrate under standard conditions into this bituminous sample, and we note down how much penetration is taking place at a particular degree of temperature under controlled conditions. So, I can say that if the penetration of the needle is greater, then the binder is soft; if the penetration is less, then the binder is hard. Broadly, we can speak in this manner if the penetration is less than the binder is hard.

So, this is how we can compare the consistency of the binder. So, the consistency of a bituminous material is expressed as a distance in tenths of a millimeter, and the amount of penetration is recorded in one-tenth of a millimeter. So, if there is one mm of penetration, then the penetration value will be 10 in that case. So, a standard needle penetrates vertically into a sample of the material under specified conditions of loading time; this is important for determining what temperature we do the measurements. The most common measurement is done at 25 degrees centigrade.

Now, here are the important aspects specifically in terms of the needle: the dimensions of the needle, the weight of this assembly, which is going to penetrate, the amount of time allowed for the needle to penetrate, and then you measure your penetration in terms of one-tenth of a millimeter. So, it says that a moving weight, the sum of the weights of the needle, carrier, and superimposed weights, is around 100 grams. And we make multiple readings; this is not a single reading. This is in this particular cylindrical measure when you are going to take these measurements of penetration. We will take at least 3 repetitions, which have to be done, and it says that they should be at least 10 mm apart and 10 mm from the side of the dish.

So, these are the temperatures that need to be ensured in this particular case. The important part is that the test procedure must be strictly followed because it can be influenced by the inaccuracy in the pouring temperature at which we are pouring the binder into this particular cylindrical measure. The size of the needle, the weight placed on the needle, and the test temperature. So, this any variation in this one will lead to a variation in your penetration amount. So, if I have a higher penetration I can call that binder as softer, if lesser penetration the binder is harder.

Another consistency test, which is used to ensure how the binder will behave, is specifically the phase change of the binder; as I mentioned, it can be semi-solid at lower temperatures, and when you increase the temperature, it may become soft. So, you might have seen that sometimes news comes up about some road sections where they are getting stuck to the vehicle tires, especially as the roads are melting. What is happening? The binder becomes soft at higher temperatures. So, for this particular one, in addition to the viscosity penetration, there is a popular test to measure the consistency, which is the softening point test. And what it does is that the softening point is the temperature at which the binder attains a particular degree of softening under standard test conditions.

So, we are going to determine the temperature at which a particular degree of softening is achieved. And it says it is an empirical measure that indicates the temperature at which bitumen transitions from a semi-solid to a semi-liquid state. So what I will do under this particular test is prepare some rings with a binder sample, and over that, a small weight will be placed. In this particular cylindrical measure, it will be submerged in water. I will raise the temperature and see when, under the weight of this particular ball, the binder in the ring moves down.

So, initially, when I started the test, this test is usually started at 5 degrees centigrade, and gradually the temperature is raised. So, the binder is in a semi-solid state, and once the temperature is gradually increased, a temperature is reached where this binder in this ring starts moving down and touches the bottom. So, this gives me an idea of the phase change that is happening in the binder. So, its purpose is to determine the temperature at which an asphalt cement cannot support the weight of a steel ball and starts flowing; this is what happens. Now this is further some of the more pictures that show how a softening point test is done.

So, these are the steel balls, these are the rings in which the binder sample is poured, and then it is placed in this outer ring; thereafter, you place these steel balls over it, and this is how the assembly is made: it is kept in a water bath, and then you raise the temperature. It says the assembled softening point apparatus is placed in a water bath with distilled water at 5 degrees centigrade for 15 minutes to bring the sample to 5 degrees centigrade, after which the ball is placed, and the temperature is raised 5 degrees centigrade per minute. So, a gradual increase in the temperature has to be made, and there may be certain binders that may be very hard. So, the distilled water may not be possible to find at those temperatures where this phase change occurs. In that case, glycerin may be required if the temperature of the softening point of these binders is more than 80 degrees centigrade, and we exactly check where the binder touches the bottom place, and that is recorded as our softening point.

So, if a binder is hard, then that particular one will require a higher temperature to experience this phase change; if a binder is soft, it may move down at lower temperatures. So, this also gives an idea about the consistency of the binder. So, after this consistency, there is one other aspect that needs to be ensured for the bituminous binder, specifically the paving binder: the resistance to aging. Just as human beings age, the binder ages similarly. Now, how binder aging happens is that binder aging occurs during the production of the mixes as well, because at that particular time, the bituminous binder, when mixed with aggregates at elevated temperatures, forms a small film, a very thin film that may be in the range of around 10 microns or even less than that.

So a very thin film is formed over the aggregates, and this thin film, when exposed to those high temperatures, undergoes loss of volatiles in the bitumen. So when this loss of volatiles happens, the viscosity of the bitumen increases, or we can say the bitumen is getting oxidized, and we call it aging of the binder. So, the viscosity of the binder is very high if this aging occurs, making the binder unsuitable at a later stage of its service life. So, some good characteristics of the binders are lost. So, that is why we want to ensure how much aging takes place and how much a binder is susceptible to aging.

So, when bitumen is mixed with hot aggregates at elevated temperatures in a hot mix plant, it forms a thin film in the range of around 8 to 10 microns around the aggregate particles. The exposure to high heat causes the loss of volatile components in bitumen. Leading to a significant increase in viscosity that makes the binder stiff, this phenomenon is called hardening, aging of the binder, and another term which is short-term hardening. Why short-term hardening? Because the binder will still undergo hardening. When it is layered and compacted after that particular one, the road will be exposed to different environmental and climatic conditions and loading conditions for a period of 20 to 30 years.

So, during that process, it will also undergo aging subsequently. So, the aging that happens during production and construction is considered short-term aging. And we want a binder that ages less comparatively. So, after the bituminous pavement is laid, bitumen continues to undergo long-term aging. So, once it is laid, what happens during the aging is considered long-term aging, which occurs during exposure to different factors. So, what is more important is when it is produced; at a hot mix plant, this is a hot mix plant where it is produced.

So, there and then, it is transported to the side, where it is laid and compacted. So, this particular process from here to here up to this one is yours; both production and construction aging, which happens during this period of time, is your short-term aging, and what happens to this particular short-term age binder during service life is long-term aging. So, for long-term aging, you should have with you the short-term aged binder because this is the aging after short-term aging; thus, long-term aging occurs during the service life. Now the tests that are widely used for the determination of aging characteristics or the aging of bitumen are the thin film oven test, the rolling thin film oven test, and the pressurized aging vessel (PAV) test. So, we have the IS specifications 9382, which is for testing the determination of the effect of heat and air by thin film oven; then we have IS 15799, which is for the aging of bitumen through RTFO and PAV tests.

Now, quickly, what is done in this particular test, in a thin film oven test, which is conducted to determine the short-term aging of a bituminous binder, is that a standard sample of around 50 grams of binder is taken, poured into the pans, and these pans have standard dimensions. Because of these standard dimensions, there is a standard thickness of the film that is constructed. So, if I pour these 50 grams of binder into this pan, approximately a thickness of 3.2 mm is created, and then this is transferred to the oven; there is a shelf over which these particular pans are placed after pouring the binder.

So, I have poured the standard requirement of 50 grams into this standard. These pans are of standard diameter as well as height, and then they are transferred to this particular oven where a rotating shelf is located. So, you can place three such pans in it, and then this rotating shelf moves at a standard speed. So, it moves at a rotational speed of 5.5 revolutions per minute, and the oven temperature is maintained at 163 degrees centigrade for a duration of 5 hours. So, with this 5 hours at 163 degrees centigrade and this revolution speed, we are trying to simulate the aging that can happen during the production and construction of the bituminous mixes.

So, once this binder has aged, you will take it out and determine its consistency before short-term aging, and you can determine its consistency after short-term aging by using a thin film oven to see how aging susceptible your binder is in comparison. You want a binder to be less susceptible to aging. Because its viscosity and other important characteristics should not be affected much by this particular production and construction process. Another modification of this thin film moment test is the rolling thin film moment test at work.

It is a rolling test, and nowadays it is preferred specifically. Again, here we take a standard weight of bitumen. These are the glass crucibles that are there. You can see they are pouring the binder into it, and once the binder is poured, it is rotated in order to achieve a good dispersion of the binder. Then it is moved again to a shelf where these bottles are inserted. So, what happens is that the container is then placed in the open oven carriage, and in this particular carriage, these are going to rotate.

So, you will place these cylindrical bottles in this particular manner, and they will rotate along this axis. So, this will rotate in this particular manner. Now, when it rotates in this particular manner, the chances of any film formation that was present in the thin film oven test are reduced, and during this particular part, there is an airflow that will be projected. So, any formation of a film is getting reduced because of an airflow, and this one rotates at a speed of around 15 revolutions per minute; the test is done at 163 degrees centigrade, and it produces the aging which we did with the thin film oven in 5 hours; here we get a similar amount of aging in 85 minutes. So, we are able to produce more short-term aged binders in a shorter duration of time, and there are reduced chances of any skin formation, specifically with this one.

So the RTFO produces a similar degree of hardening as a thin film oven, but in a shorter period of 85 minutes, and can handle more samples simultaneously because you can insert around 8 bottles in this particular one in one go, compared to the 3 pieces that are usually used in the case of a thin film oven. And it is preferred for testing modified binders because its rotating action prevents any skin formation on the sample. So this is again some of the common issues for which this rolling thin film oven is now widely used. Now, the last one that comes up under the ageing protocol is the pressure age vessel, which is to see how the ageing occurs during the service life of the bituminous mixes. So for this particular one, a vessel that is used is known as a pressure ageing vessel because here you do the ageing without raising the temperatures to higher levels by applying vacuum and pressure at higher temperatures ranging from 90 to 110 degrees Celsius, and by applying pressure, you are trying to simulate the ageing that can happen over a period of around 5 to 10 years of life.

So, in a pressure ageing vessel, this is how a pressure ageing vessel looks; this is a peak of a pressure ageing vessel where actual testing is undergoing. So, here again, there is a pan. So, the short-term aged binder has to be used for this pressure-aging vessel. So, what you obtain from the thin film oven, or the rolling thin film oven has to be used in this particular one. Again, as a quantity of RTFO is a standard quantity to be used, when you pour it into these standard pans, you get a standard thickness.

And then this pressure vessel is subjected to an air pressure of around 2.1 megapascals and temperatures of 90, 100, and 110 degrees centigrade, depending on the grading of the binder; harder grades or softer grades are present. So, we will discuss the later stage, but it is subjected to a temperature of around 100 degrees centigrade, and this test is then conducted for a period of around 20 hours. So, the binder obtained from it is subjected to a small process to remove any entrapped air, and once that is completed, we have the short-term aged binder as well; this includes short-term aging, short-term aged, and long-term aged. So, we will have the short-term aged binder and the long-term aged binder. Now we can compare the characteristics of these binders, which may be in terms of softening point or viscosity, how much the viscosity changes once it undergoes short-term ageing, and how much it changes when it undergoes long-term ageing.

So these are some standard processes to determine this particular. Now another test is done to ensure the quality of a binder for road applications and bituminous applications regarding purity. Normally, what we get from the refining of petroleum crude at the standard refineries is good quality binder, which is mostly completely soluble in solvents like toluene or trichloroethylene. But, if for any reason during transportation or production certain impurities are introduced, we can ensure this by checking the dissolution of these binders in standard solvents, and there is an approximate standard process that is done as per IS 1216. It says approximately 2 grams of binder sample are placed in a conical flask; this is there. So, to which 100 ml of trichloroethylene or toluene is also preferred for dissolution, the mixture is then filtered through a Gooch crucible; this is a specific crucible, and the insoluble residue, which is collected on the pad, is washed, dried, and weighed.

So, I can understand how much residue is retained on this particular one; this will give me an idea of how much impurity is present. So, this specifically refers to the impurities; as I said, when you get them from refineries, the chances of impurities are quite low, but during transportation, when moving it from different tankers, if some impurities are intentionally introduced, this is a check that can be done because, as I mentioned, nowadays it has become a very costly material. Another aspect that needs to be ensured whenever a material is to be used is whether, as I mentioned, it has volatiles in it. This is a hydrocarbon; bitumen is a hydrocarbon, so when you raise the temperature, fumes are generated, and these fumes can catch fire. So normally the temperatures used in production are much lower compared to the temperatures at which it can catch fire.

But it is also important to ensure, from a safety aspect, what the safe handling temperatures are. So, for that particular one, we have the flash and fire point test. So it says that when heated to a sufficiently high temperature, bitumen emits vapors that can ignite upon exposure to a flame. So, you can see that this is a binder hot mix plant, which caught fire for this reason. So, if there is a certain mishap that can occur if we are not able to control the temperatures to which these binders get heated. So, one temperature that is referred to as the flash point is the temperature at which bitumen can be safely heated without the risk of sudden ignition, and this temperature is much lower than the fire point, where the material actually starts to combust.

So, two temperatures are referred to as the flash point and the fire point; what we measure is the flash point, which is normally 10 to 15 degrees Celsius lower than the fire point. And we will try to ensure that the flash point of the binder is quite high compared to your production temperatures. So, the flash point of a material is the lowest temperature at which the application of a test flame causes the vapors from the material to momentarily catch fire in the form of a flash. So, I will heat a binder sample, and I can reach temperatures where vapors will be generated if a flame is brought near it.

If you see some flashes, then you can call it a flash point. And if you further heat this particular one, then the material starts burning; it ignites, so that is your fire point, which is there. So we do not check for the fire point; we check for the flash point, and there is a standard Cleveland open cup method where you pour this binder into this particular cup, gradually heat it, and bring a flame to the top of it to see where the flash occurs, because the vapors are formed at higher temperatures. So, normally it is well around 220-250 degrees centigrade; it is in the range of 220-250 degrees centigrade for different bituminous binders. So, we do the production of bituminous mixes at temperatures of 150-180 degrees centigrade. But still, one needs to ensure, from a safety standpoint, that due to some contamination or impurities, there may be chances that the flash point may be lower.

So, the flash point is also used to detect the presence of some volatiles, as I mentioned, because of some impurities; specifically, what happens with kerosene is that its presence may result from switching transport tankers, as this is from one tanker to another, and when the cleaning of these bitumen tankers is done, at that time some remains of kerosene may be there, which is highly volatile, so that may reduce the flash point. So that is why the flash point is to be ensured for the binder samples that you are going to use for your construction purposes. Another test that is used is your ductility test. Now, in this particular ductility test, a binder sample is taken in a special mold, and you stretch the binder sample. When you stretch, you are going to measure how much elongation or how much you can stretch a binder sample.

You will always prefer that it be stretched to a good amount before it finally runs. So, a binder should show a good amount of ductility, and it has been reported that a binder with good ductility shows good performance, specifically in terms of the cracking of those bituminous mixes. So, the ductility of bitumen is measured by the distance in centimeters it is stretched before breaking. So, this is a special briquette in which it is poured. Standard dimensions are given in 1208 part 1, and when you stretch it in a water bath, to maintain a standard temperature, it is kept in the water bath, and it is a stress. So, here it is getting stressed; both ends are getting stressed, and you stretch it at a standard rate of 5 centimeters per minute.

So, you are going to stretch it at a standard rate, and specifically, one important aspect is to ensure that the specific gravity of the binder and the water is more or less the same. So otherwise, what happens if the density of water is quite less, then it may float; or if this particular is more, then it may float. So we try to increase or decrease the density of the water by adding salt; we increase it by adding salt, and we decrease it by adding some alcohol to it. So, these are again some precautions that are to be followed as per IS 1208, and then the ductility is measured; there are minimum values specified for the binders, which should have at least this much elongation. It is preferred if we do this ductility measurement on an aged binder because that is the short-term aged binder, which will actually be available in the field after construction.

And for research purposes, this can also be done at lower temperatures instead of 25 degrees centigrade, at 15 degrees centigrade, and at 4 degrees centigrade. But when it is done at lower temperatures, we normally reduce the rate at which these two ends are stretched as well. So, instead of 5 centimeters per minute, the rates are many times reduced to 1 centimeter per minute when we are doing it at lower temperatures, like 4 degrees centigrade, for the ductility measurement. But the standard one is done at 25 degrees centigrade at a pull rate of 5 centimeters. Now, this table shows you the requirements of these different properties that we have measured, and here you can see it states the requirements of paving bitumen.

Now, in this paving bitumen, there is one new thing: there are four different grades, which are shown here. But each grade has requirements in terms of penetration, absolute viscosity, kinematic viscosity, flash and fire point, solubility, softening point, and then there are ductility and viscosity ratio. So, all these tests we discussed. So, these grades are formulated for their applications in different regions, specifically where you require them, depending on the maximum temperatures and the lower minimum temperatures that occur in different regions. The amount of loading that is going to come is different. VG40, for the beginning part, we can say in general that VG40 is the hardest grade, the stiffest grade compared to VG30; then we have VG10 and VG20, and VG10 is the softest grade.

Now, here you can see that this gives what should be the requirement of a penetration test done at 25 degrees centigrade for, say, VG20; it says the minimum value of penetration should be 60. Similarly, it says the absolute viscosity value should be in the range of 1600 to 2400, and as I mentioned, these are harder grades. So, the viscosity requirement of VG10 is 800 to 1200 poise, and that of VG40 is 3200 to 4800 poises. So, as this is a harder grade, the absolute viscosity will be higher for VG 40. Similarly, it will be there for kinematic viscosity as well, where the requirement is a minimum of 250; here, it states that the requirement is a minimum of 400 centistokes.

Then, the flash point, as I mentioned, has to be more than 220 degrees centigrade in all cases. Solubility and purity should be ensured, and it should be more than 99 percent soluble in a solvent like toluene or trichloroethylene. So, the softening point for a softer grade of binder is less, and for a harder grade of binder, it is more, and the requirement is given; as I mentioned, ductility is a good test to be conducted on a short-term aged binder.

So, after doing the aging test on residue from the rolling thin film oven, it says... So, it is an aged sample; these are the short-term aged samples that you are using. So, here what you do is a ductility measurement, and it says that the ductility values should be at least 75 centimeters for the softer grades and for the hardest grade at least 25 centimeters. So, this is the ductility requirement: if it does not meet the requirement, the binder cannot be accepted for your use and viscosity ratio, because, again, the binder should not be highly susceptible to aging. So, this is the viscosity of the aged binder with respect to the unaged binder. So, we are going to measure the absolute viscosity at 60 degrees centigrade of unaged and aged samples, and this ratio should not be more than 4.

So, this is what is ensured through this IS 73:2013 paving bitumen specification. So this is how important it is to understand what the individual characteristics required for the binders are for different applications. Now, MoRTH has provided a table that specifies where to use VG10, VG20, and VG30. It states that if the lowest daily mean air temperature is more than 0.10 degrees Celsius and the maximum daily mean temperature is less than 20 degrees Celsius, you can use VG10 binder.

So, depending on the highest daily mean temperature and the lowest daily mean air temperature, you can decide this grade. And similarly, let us say for this particular run, more than 30 degrees centigrade, and this is more than minus 10 degrees centigrade, you can use it for VG30. Similarly, it is given for VG10, VG20, VG30, and VG40 in your IS 73 specifications. So, on the basis of the temperature requirements that occur in different regions, these different grades of binders are used in roads. But our important aspect is that we need to ensure what the requirements are in terms of different parameters: viscosity, the softening point, penetration, ductility, and whether the binder supplied to us for that particular use meets those requirements. It has to be ensured properly; if not, we have to reject that particular one and look for another source that meets all the requirements. So, this is all about the characterization of bituminous binders. Thank you.