Introduction to Transportation Engineering
Prof. K. Sudhakar Reddy
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture - 29
Pavement Materials – III

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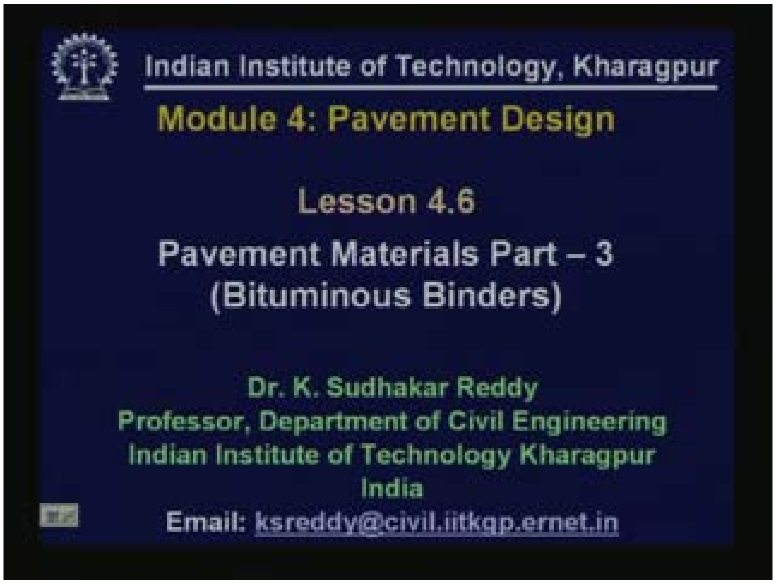

This is the sixth lecture in the module pavement design. In this lesson we will be dealing with bituminous binders.

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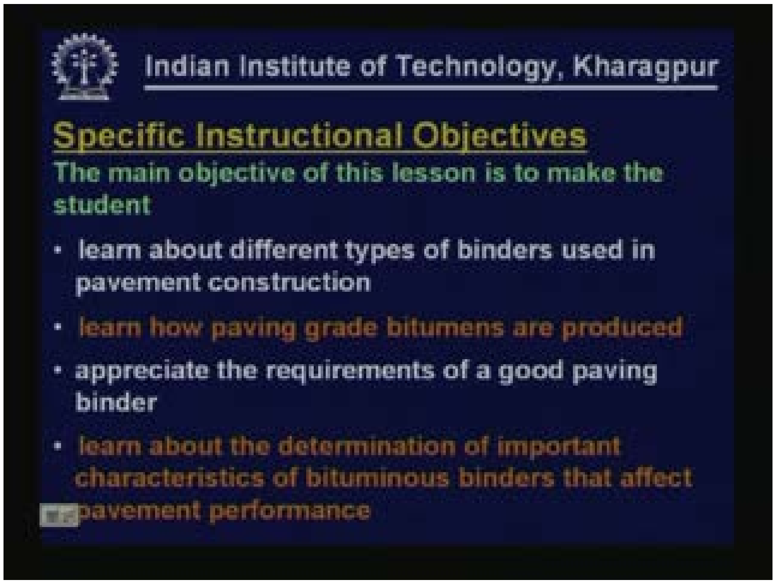

The specific objective of this presentation is to make the student learn about different types of binders used in pavement construction, learn how pavement grade bitumens are produced and also make the student appreciate the requirements of good paving binder. It is also excepted that the student would learn about the determination of important characteristics of bituminous binders which affect pavement performance.

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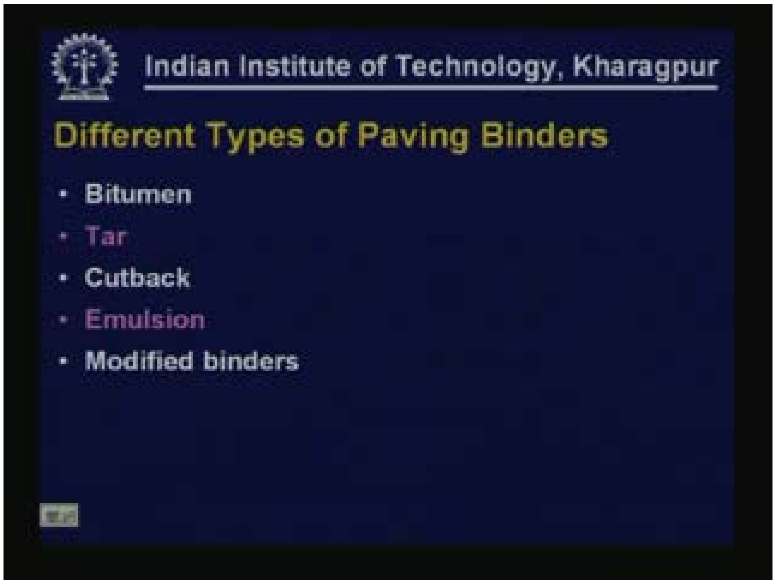

There are various types of paving binders. As we understand from the word ‘binder’ this is the material that is used to bind.

We are especially talking of pavement binders that are used in flexible pavements where we normally use bituminous binders. Of course in cement concrete pavements the binder used is cement and in other stabilized layers we can use lime and other types of binders. Since we are talking about flexible pavements the binders that we are going to be talking about will be bitumen and other related materials. So we have this list bitumen, tar, cutback, emulsion and modified binders. We will be talking about all these binders in this lesson and the subsequent two lessons that will be following this particular lesson.

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Let us first talk about bitumen and tar.

I am talking about these two terms together because often these two are confused for each other. Rather most people do not understand the differentiation between tar and bitumen. Bitumen, of course is the most commonly used binder that is used nowadays whereas tar is hardly used nowadays. We have to understand that bitumen and tar are two distinctly different materials of different origins having different chemical composition and naturally different physical properties.

Bitumen is a dark brown to black color naturally occurring or a material that is produced by petroleum distillation. So bitumen occurs naturally or can be produced by distillation of petroleum which is dark brown to black in color whereas tar is manufactured from destructive distillation of bituminous coal. Tar is very highly temperature susceptible compared to bitumen and its use is more health hazardous compared to the use of bitumen.

We used a term temperature susceptibility, we will be discussing about this term in greater detail in subsequent slides. What we mean by temperature susceptibility is the properties of tar change more significantly with variation in temperature compared to what would happen to bitumen for similar variation in temperature. For specific purposes would not want the binder properties to be changing so significantly. We know the properties of bitumen and then tar are going to be different at different temperatures but we don't want these materials to be undergoing quiet drastic changes with variation in temperature.

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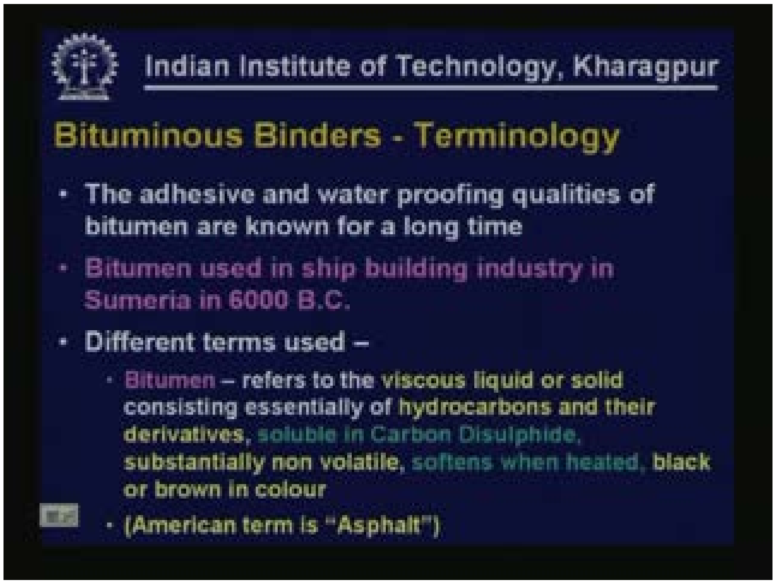

Tar of course is not regularly used nowadays because it is not that easily available and its properties compared to bitumen are not that good as for as pavement construction is concerned. So our discussion will be mostly focused on bitumen and bituminous binders. There are various terms that we commonly use. Before we understand each one of those terms it is important to appreciate that the adhesive and water proofing qualities of bitumen have been known for a long time.

Of course bitumen used in pavement construction and other areas is mostly for its adhesive characteristics and water proofing characteristics. Bitumen has been used in ship building industry in Sumeria as early as 6000 B.C. Various terms that we normally use in describing these binders are bitumen. This refers to the viscous liquid, it can be in solid form also depending on the temperature at which it is maintained consisting essentially of hydrocarbons and their derivatives and soluble in carbon disulphide, substantially non volatile, this is the material which softens when heated and it is black or brown in color. This is the general description of bitumen.
The term that is used in American literature for describing this material is asphalt whereas asphalt has got a different meaning in British literature.

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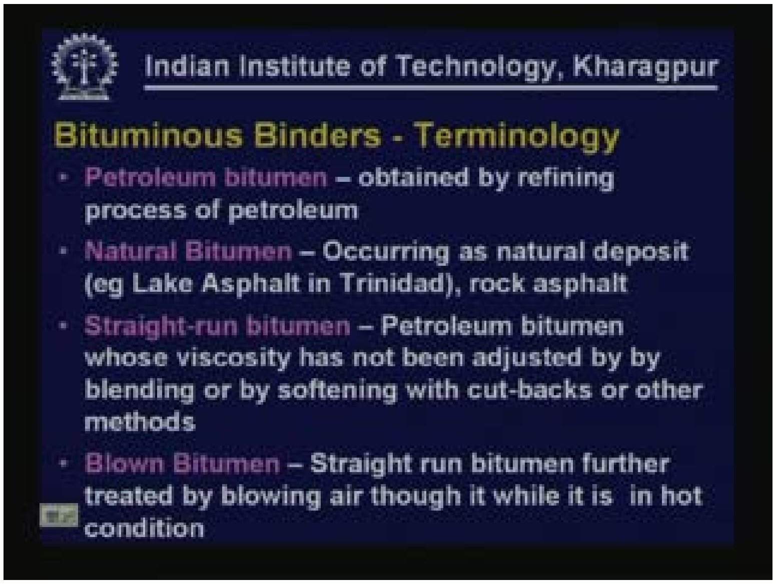

Petroleum bitumen is that bitumen that is obtained by refining petroleum. We will discuss about refining process of petroleum and how bitumen is obtained. So petroleum bitumen is that bitumen which is obtained by refining petroleum. Natural bitumen is that bitumen which occurs naturally as deposits in lakes a typical example or famous example being the lake asphalt in Trinidad. It can also occur as rock asphalt or rock deposits.

Straight run bitumen is the bitumen that is produced by petroleum refining whose viscosity has not been adjusted by blending with other materials or by softening it with cut back or other solvents or any other methods. so this the bitumen that comes straight out of the refinery or it is the processed byproduct that comes after refining petroleum whose viscosity has not been adjusted by adding any solvent or any other material.

Blown material is a straight run bitumen but which is further treated by blowing air through it when the bitumen is in hot condition. The bitumen which results out of this process is called as blown bitumen.

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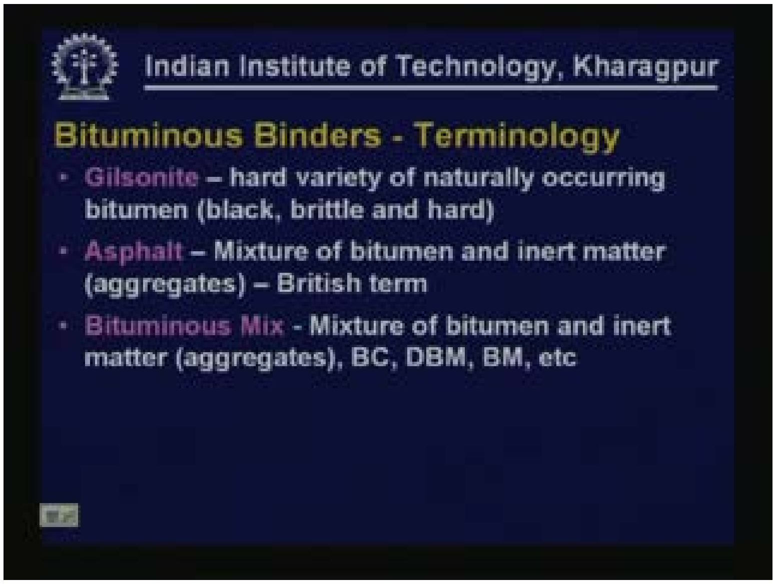

Gilsonite is a hard variety of naturally occurring bitumen which is black, very hard and brittle. This is a material often used to add to normal bitumens to increase their hardness increase their stiffness but as it is gilsonite by itself is not normally used in any pavement construction.

Asphalt is a term as I indicated in British literature to represent the mixture of bitumen and inert material which are aggregates. So asphalt in British literature means it indicates mixture of bitumen and aggregates whereas in India and many other countries we use the term bituminous mix which again is a mixture of bitumen and inert matter which are aggregates. And various terms that we use for bituminous mix depending on the composition, depending on the content of bitumen that we use are bituminous concrete, dense bituminous macadam, bituminous macadam represented by BC DBM BM and so on.

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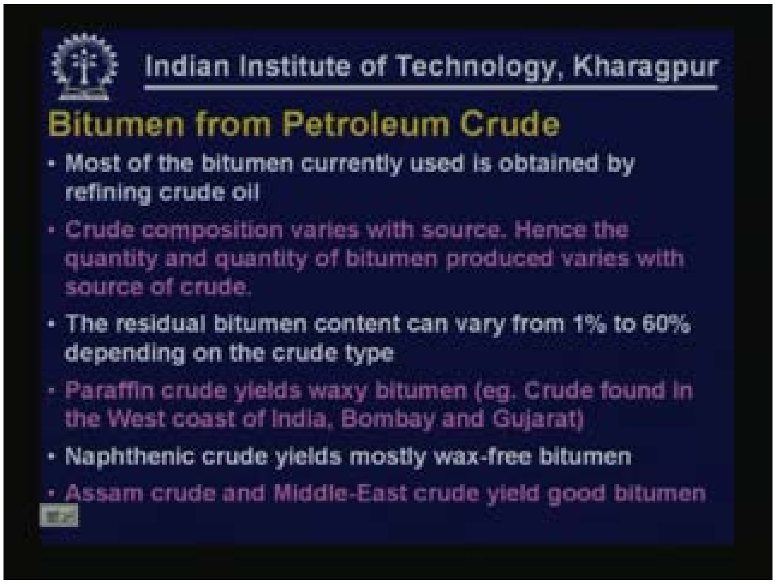

As I said, most of the bitumen that we use currently is obtained by refining crude oil. The crude composition varies from source rather it varies with source hence the quantity and quality of bitumen that can be obtained from a given source will also be different. The residual bitumen that is the quantity of bitumen that can be obtained from different sources of crude varies from about 1% to 60% depending on the crude type.

Paraffin type crude yields waxy bitumen. This is bitumen which contains high percentage of wax. Especially the crude found in the west coast of India that is Bombay and Gujarat contains higher wax content. we will subsequently discuss the implication of having high wax content which is in terms of its temperature susceptibility this bitumen having higher wax content is going to be very brittle, very hard at lower temperatures but it is going to be very soft at higher temperatures. So, depending upon the content of wax that is going to there in bitumen the properties are going to be changing significantly with variation in temperature.

Naphthenic crude yields usually wax free bitumen. The Assam crude and the Middle East crude yields good bitumen as far as wax content is concerned and also as far as the performance when used in pavement construction is concerned.

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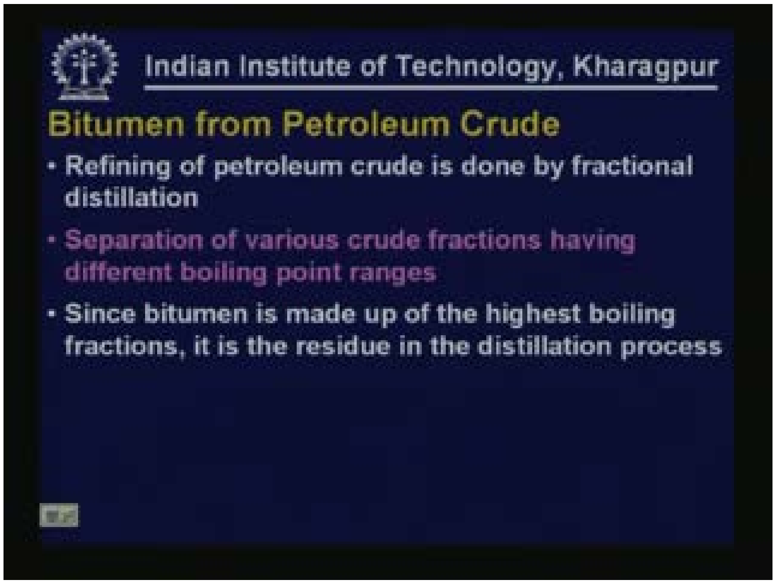

Refining of petroleum crude is usually done by fractional distillation. Petroleum crude consists of various components having different boiling points. As a result these constituents are separated by fractional distillation process. Since bitumen is the one having the highest boiling point among these fractions it is a residue that is going to be available after the distillation process is completed.

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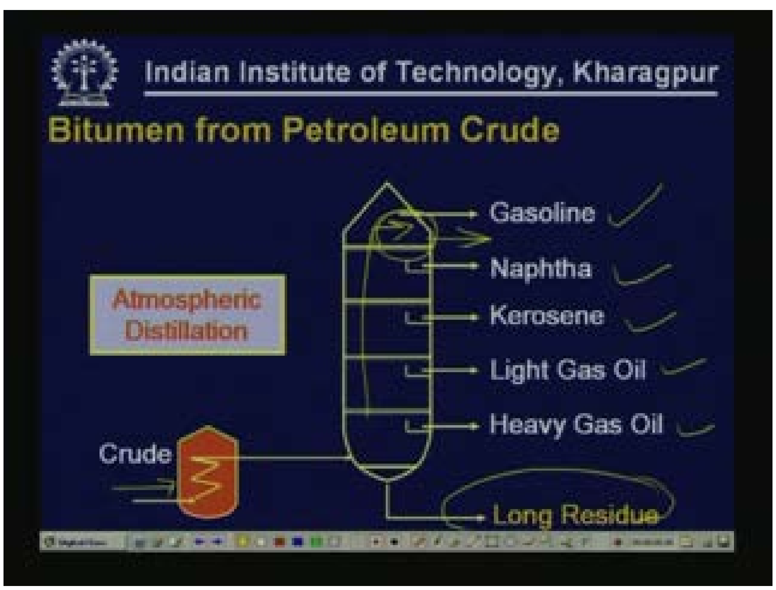

This is a schematic arrangement of the first step of refining of crude which is atmospheric distillation. Here the crude is fed into this and then heated and then fed into this tank so the volatile matter the lighter fraction gets evaporated first and then they reach the top and then get condensed here, there is an arrangement for condensing those vapors and then an arrangement to remove the condensed material. So, obviously the material having lower boiling points is collected at the top gasoline which we call as petrol then naphtha, kerosene, light gas oil, heavy gas oil and what is going to be remaining at the bottom is a long residue. Possibly in terms of commercial value all these materials may be of much greater importance compared to what is available at the bottom as long residue.

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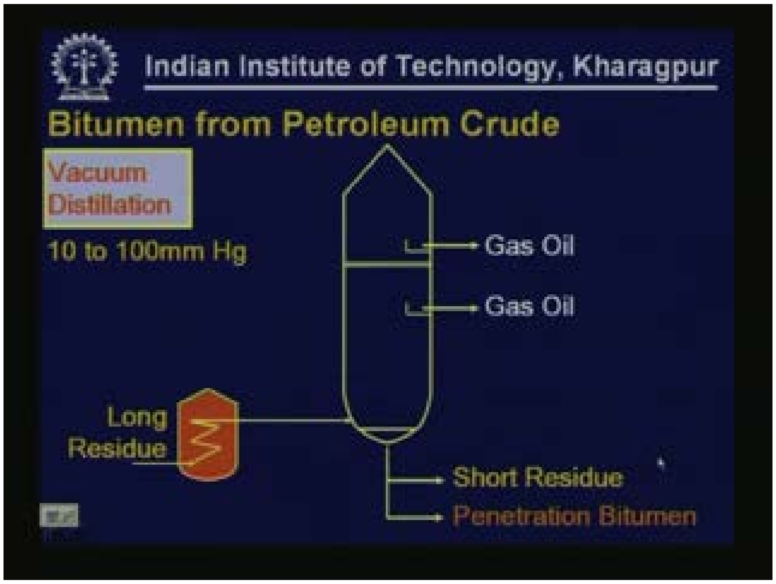

But the long residue is not a material that can be directly used for pavement construction. This requires further processing because it would still contain certain amount of gas oil and other components so this again has to be distilled but further distillation is done under vacuum. So this is the amount of vacuum that is applied and these are the components that are going to be produced. And what we are interested in is the short residue that is produced where this could as well be the penetration bitumen or the paving grade bitumen. We can get bitumens having different consistency at the end of vacuum distillation. it is possible to use them directly depending upon what type of material is available, what consistency could be attained, or it may require further processing before the same can be used in pavement construction.

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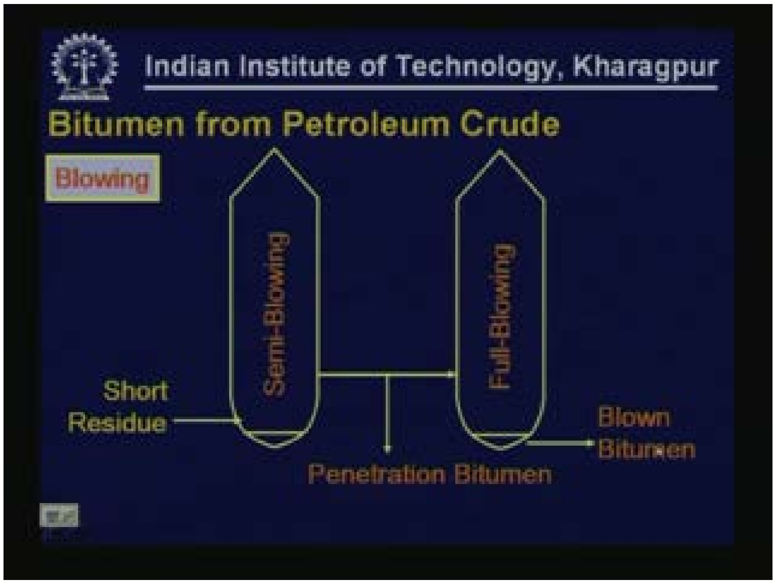

As we see here short residue often has to be blown to get the commonly used pavement grade bitumens. Blowing is a processing of blowing air into the bitumen when it is in hot condition but we normally go for semi-blowing to obtain penetration grade bitumens. We also go for further full blowing. Whether it is semi-blowing or full blowing it depends upon the duration of blowing, temperature at which the blowing is done and other conditions. The fully blown material is not normally used for pavement construction, it is used for possibly roof treatment and other industrial purposes. But what we normally use is either the short residue or the semi-blown bitumen from which we can get bitumens of different penetration or different consistency.

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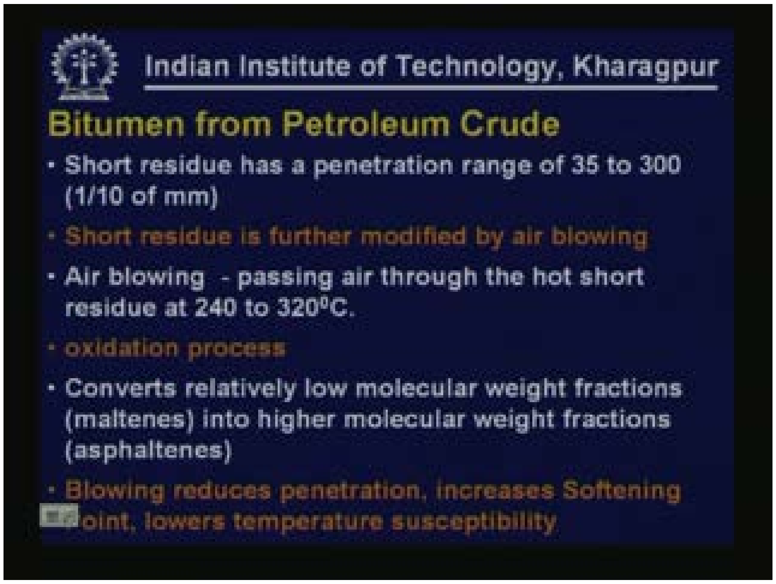

The short residue has a penetration range of about 35 to 300 that means about 3.5mm to 30mm penetration.

We will discuss about the term penetration subsequently. But penetration is a term that indicates the consistency. The 35 penetration is a harder grade whereas 300 penetration is a softer grade. So a wide range of penetrations can be obtained after short residue depending on the distillation process. The short residue as we have indicated in the previous slide is normally further processed or further modified by air blowing. Air blowing is a process of passing air through the hot short residue at about 240 to 320 degree centigrade.

What happens in blowing is normally the oxidation process takes place. Oxidation converts the relatively low molecular weight fractions called as maltenes into higher molecular weight fractions known as asphaltenes. Blowing normally reduces the penetration that is it makes the binder harder, increases the softening point, another time we use to describe the consistency of the binder. It also lowers the temperature susceptibility of the binder. That means the properties of the binder are not going to be changing significantly with variation in temperature if these binders are blown.

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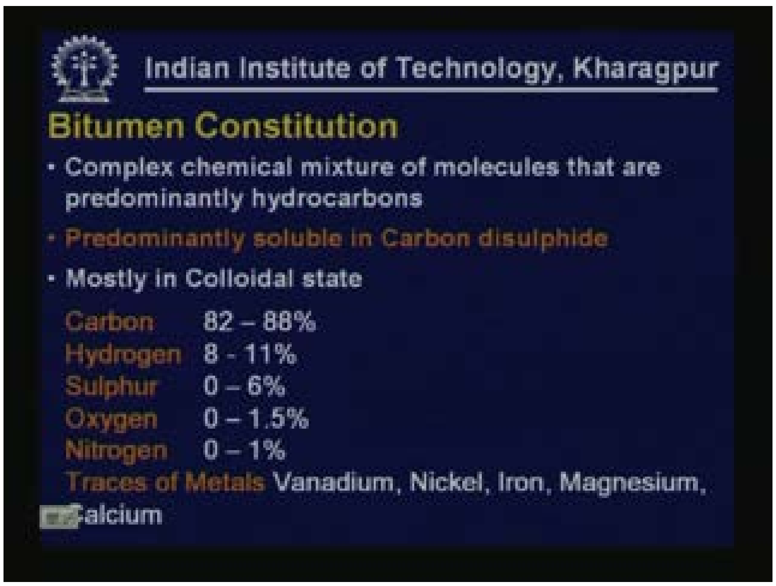

Bitumen is a very complex chemical mixture of molecules that are predominantly hydrocarbons. it is normally very difficult to find out the exact composition of bitumen and for most practical purposes as far as pavement engineering is concerned knowing the exact chemistry of bitumen has not been found to be of great importance because the performance has not been significantly correlated to the bitumen chemistry so the effort of doing very complicated testing process to find out the exact chemical composition of bitumen has not been found to be worth.

However, whatever literature indicates to us tells us that these are predominantly soluble in carbon disulphide, it is mostly in colloidal state, its composition typically is carbon 82 to 88%, hydrogen 8 to 11%, sulphur 0 to 6%, oxygen 0 to 1.5%, and nitrogen 0 to 1%. One can also find traces of metal such as vanadium, nickel, iron, magnesium and calcium and so on in bitumen.

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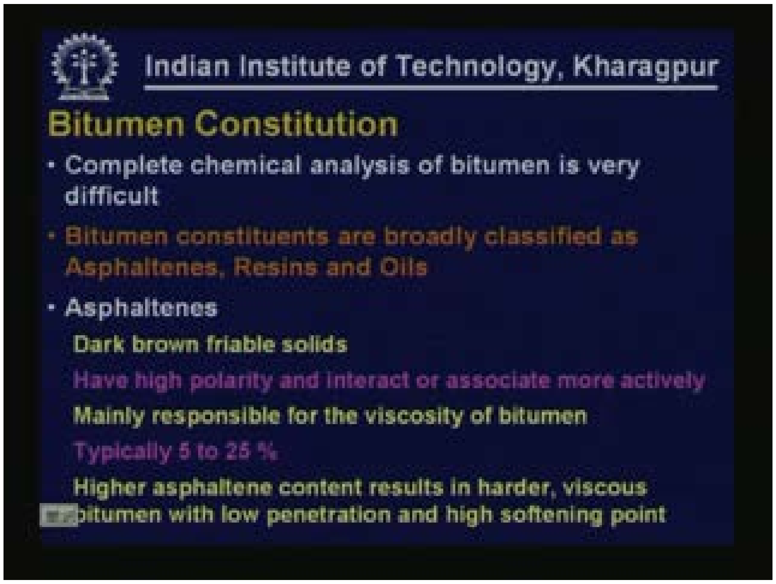

As I just mentioned complete chemical analysis of bitumen is very difficult. The bitumen constituents are broadly classified as asphaltenes, resins and oils.

Asphaltenes are dark brown friable solids, they have high polarity and interact or associate more active. These are the active constituents of bitumen (Refer Slide Time: 20:29) and these are mainly responsible for viscosity of bitumen, stiffness of bitumen and other engineering properties of bitumen. Typically the percentage of asphaltene in bitumen can vary from 5 to 25% depending on the source of crude and also the process that is adopted to obtain this paving grade bitumen, that is, how the distillation is done, how blowing is done depending on all these things the percentage of asphaltene can vary to one source to another. Higher asphaltene content results in harder viscous bitumen with low penetration and high softening point.

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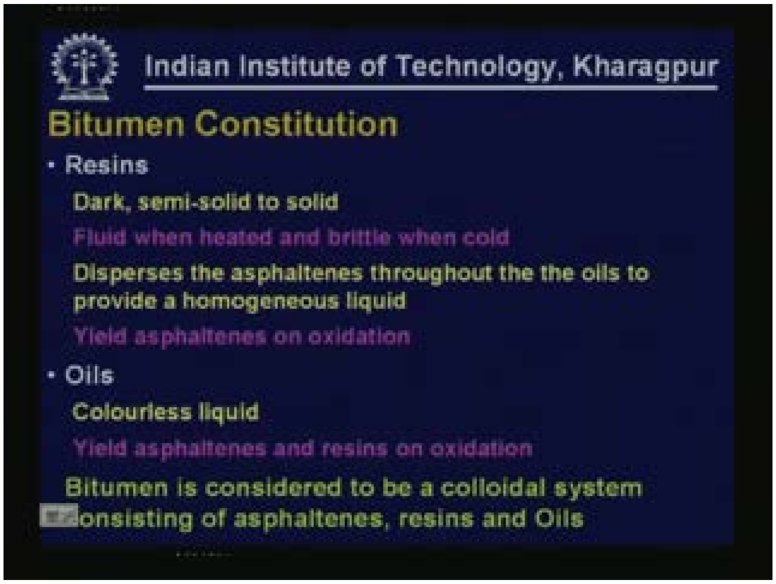

The next component which is resins is a dark semi-solid to solid material which is fluid when heated and brittle when cold. This is the material that disperses asphaltene particles or asphaltene matter throughout the oils, oil is the other component that bitumen has so the asphaltene is dispersed in oil with the help of the resins to provide a homogenous liquid. The resins are oxidized by various processes they get transformed into asphaltenes. So you can find that compared to normal bitumens bitumens having oxidized or aced or blown have more percentage of asphaltenes compared to the original bitumen.

The other component is oil which is a colourless liquid and which actually is a medium in which the asphaltenes and resins are in a colloidal state. These oils yield asphaltenes or resins on oxidation. Depending upon how much oxidization takes place oils can get converted into resins or in turn it can get converted into asphaltenes and accordingly the properties will change. Bitumen is considered to be a colloidal system consisting of asphaltenes, resins and oils.

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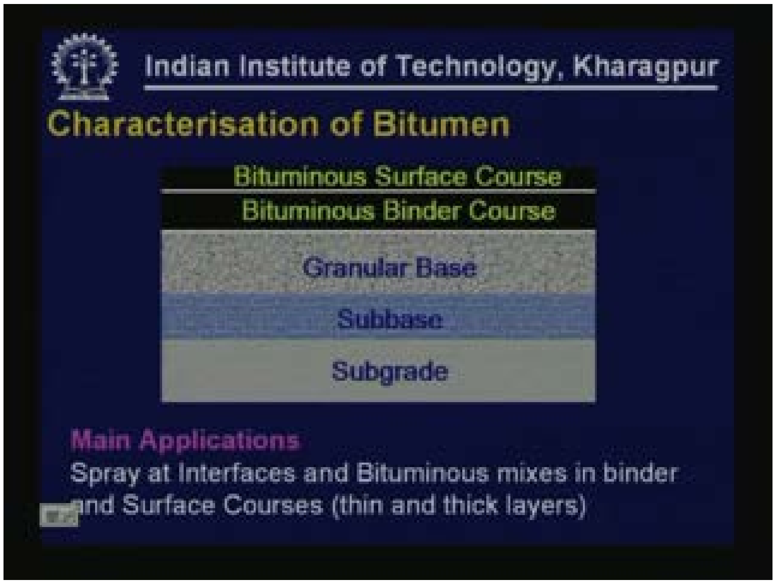

Before we understand the properties of bitumen and the need to characterize this particular material let us understand where this material is used in , what is the requirement of each one of those components of pavement and accordingly what properties the binder should have if it is used in a particular location or particular part of the pavement. Typically bitumen is used in different parts of pavement. It is used in interfaces between bituminous layer and granular layer, between two different bituminous layers as you see here (Refer Slide Time: 23:48) but these are very thin layers which are formed by spraying the bitumen on the surface. This is one aspect.

You should have bitumen which can be sprayed and which will bind two different layers. The two different layers can be granular and bituminous or bituminous and bituminous. Other than this we use bitumen in bituminous courses, bituminous binder course and bituminous surface course. Surface course is usually a thin layer ranging from 20mm to 40 or 50mm.

Typically bituminous concrete is provided with 40 to 50mm thickness. This is a surface layer provided to cater to the demands at surface whereas bituminous binder course is the main bituminous layer main structural layer which provides longevity to the pavement. Hence the requirements of bitumen in a binder course and requirements of bitumen in a surface course are definitely different because surface course is subjected to different conditions and binder course is subjected to different conditions. So we have to understand these parameters or these requirements of bitumen when it is used in different components. Therefore the main applications are it has to be used as spray at interfaces and in bituminous mixtures either in binder course or in surface course either in thin layers or in thick layers.

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When we study bitumen there are various aspects of bitumen that we need to understand. These are; we have to test the binder for its purity. Because if somebody is using the binder in pavement construction we have to ensure that good quality bitumen is being supplied so what we should know is what is expected of a pure bitumen and also we should understand how to test for its purity.

Next thing is the aspect that is related to safety in handling the bitumen because bitumen is going to be heated and when heated we have to understand that whether it is safe to use and at what temperature it is safe to use. We have to have some idea about the cohesive properties of bitumen, also understand the adhesive capability of bitumen to aggregates that we are going to use in a particular project as these aggregates could be of different nature, we also have to understand how workable bitumen is going to be or how fluid or what is the consistency of bitumen for different operations.

If you want to spray it can bitumen be used as it is at normal temperature, can we spray it or can bitumen be mixed with aggregates at normal temperatures, obviously not. So we have to understand what is the fluidity that is required for a spraying operation, what is the fluidity or consistency required so that it can be mixed with aggregates so that it can be laid in a pavement layer and then compacted. Therefore different operations would require different consistencies or fluidity. Therefore we have to understand this aspect and we should also be able to quantify the consistency and then have specifications for different operations. Another important aspect is the binder has to be durable during service life of a pavement.

We cannot have a binder which undergoes drastic changes within four to five months time and because of the climatic conditions and because of what it is subjected to during its service life it lasts only for four months or six months and as a result it undergoes so many changes and the pavement starts failing. We do not want to have such situations. So the binder that we are going to have should be sufficiently durable in terms of its properties and we have to have specifications as to what change can be permitted over some time period and what is an acceptable durable binder, thus we need to understand this aspect.

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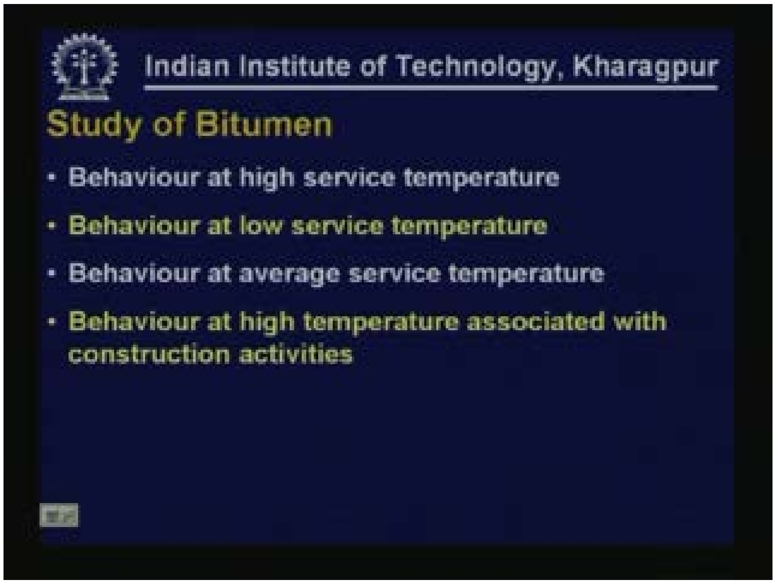

When we study bitumen we by now understand that bitumen is a material whose properties vary with temperature. So there are different temperatures at which we have to study this material because bitumen is going to perform and bitumen is going to be used at different temperatures starting from its construction operation to its service life.

We need to understand the behavior at high service temperature. Service temperature is the temperature of the pavement during its service life period may be ten years, fifteen years, twenty years. Now what are the high temperatures that the binder or the bituminous pavement is going to be subjected to? Typically these can be 20, 30, 40, 50, it can even be 70 degree centigrade if we are talking about areas which are having very hot climatic conditions. And we are also interested in understanding the behavior of binder at low service temperatures in winter. We are concerned about this especially when we have low temperatures as low as –10, –15, and –20 so the bitumen is going to have different properties and therefore the bituminous mix is going to have different properties, this is our main concern.

And bitumen at average service temperature can be 25, 30 we are not talking about very high temperatures, we are not talking about very low temperature but we are talking about average temperature at which the bituminous pavement is going to carry large number of repetitions. There may be very high temperatures may be for one week in a year similarly very low temperature is also going to be there for a very short time period but most of the time period the temperature is within a middle range. That is the time period during which most of the loads are going to be applied. So we need to understand the behavior of bitumen at that temperature range.

Similarly we also need to understand the behavior of bitumen at very high temperatures associated with construction activities. Because we are going to heat the bitumen to 150, 160, or 170 degree centigrade for mixing it with aggregates and then laying it so we also need to understand how the bitumen behaves at high temperatures.

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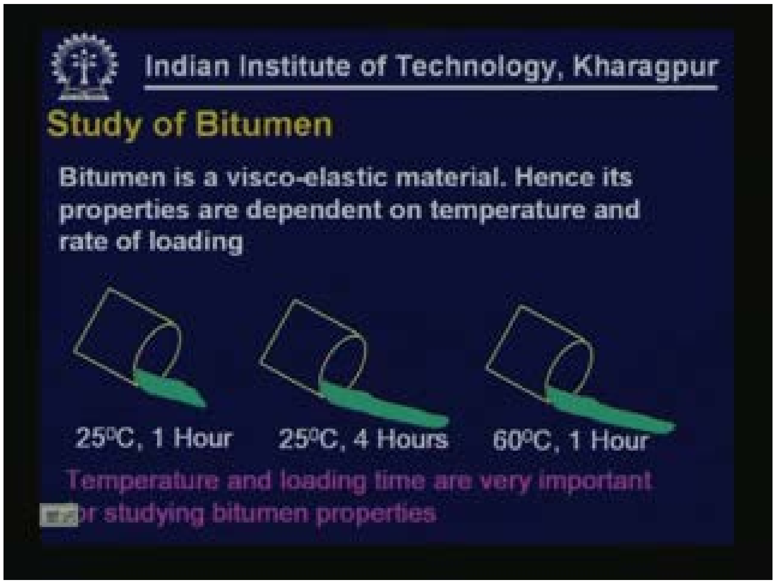

We can see the behavior of bitumen with time and temperature. As bitumen is a visco-elastic material its properties are going to be dependent on temperature as well as rate of loading. This sketch here (Refer Slide time: 31:15) illustrate in a simple manner what is going to happen to the bitumen, at which time and temperature. the first sketch is let's say when the bitumen content is stripped at a temperature of 25 degree centigrade after one year let us assume this is the amount of flow that we observe but same binder at the same temperature after four hours is going to be flowing much further. But similar amount of flow can be obtained within shorter duration of one hour but at higher temperature what this indicates to us is that the flow of bitumen is a function of time period that we allow and also the temperature at which the flow is allowed.

The temperature and loading time are very important for studying bitumen properties. Whenever we talk about a test that is to be conducted on bitumen to understand its engineering properties we always specify the temperature at which the bitumen is to be tested.

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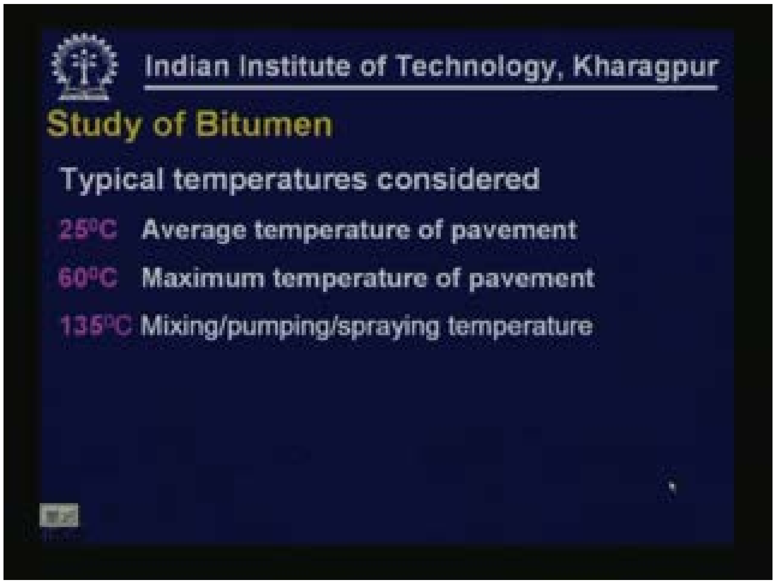

The typical temperatures that we normally consider for testing bitumen are 25 centigrade. This is considered to be the average temperature of pavement. It doesn't have to be true for all locations all places but typically this is the average temperature so many of the tests are conducted at a temperature of 25 degrees centigrade. The maximum service temperature of pavement is normally considered to be 60 degree centigrade. Although we now know that the maximum service temperature can be even much higher than this. For some operations like mixing, pumping or spraying temperature to understand the behavior of the bitumen we normally use a temperature of 135 or in some test we also use a temperature of 150 degree centigrade.

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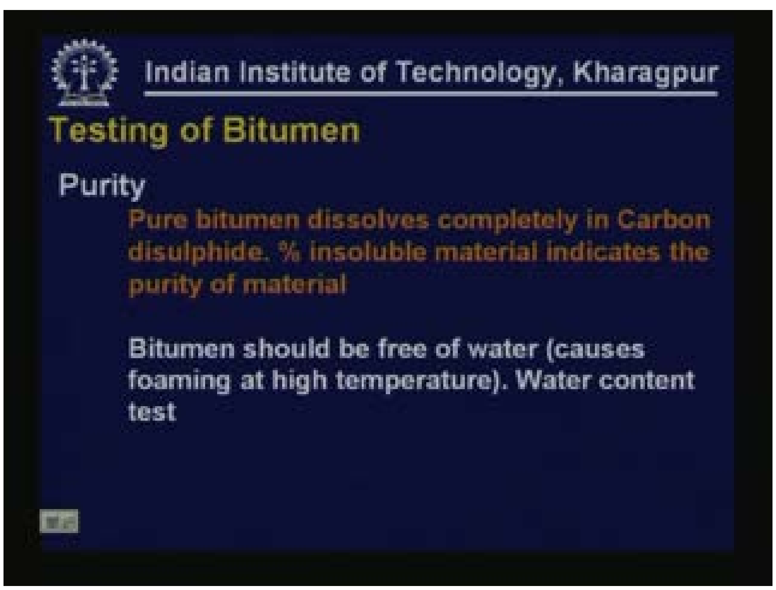

For testing purity there is a simple test pure bitumen dissolves completely in carbon disulphide. The percentage of insoluble material after it is dissolved in carbon disulphide then the percentage of insoluble material indicates the purity or rather the impurity of the material. Bitumen also should be free of water because the presence of water in bitumen causes foaming at high temperatures so there is a water content test for this.

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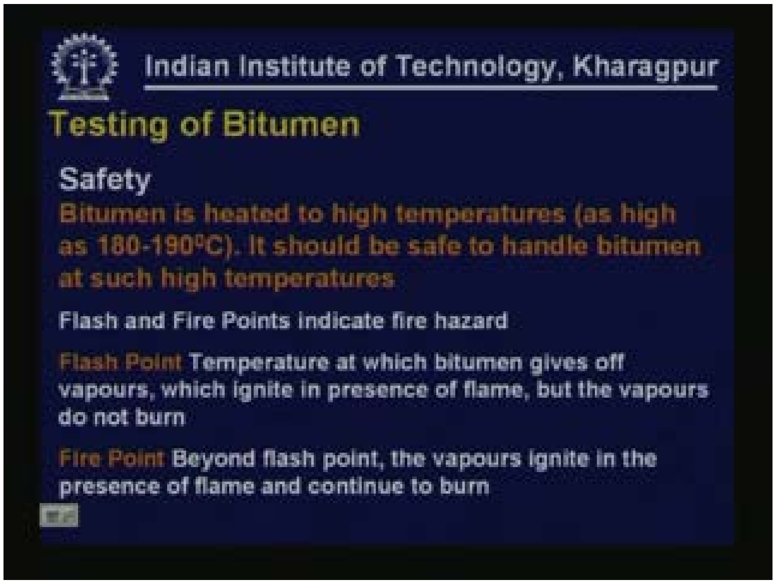

As bitumen is going to be heated to higher temperatures as high as 180 to 190 degree centigrade to understand the safety of bitumen when it is operated at such higher temperatures it should be safe to handle bitumen at such high temperatures. There are couple of test that are done to identify whether bitumen is hazardous when it is heated to such high temperatures, flash and fire points are the two tests we can conduct. Flash point is the temperature at which bitumen gives off vapors which ignite in the presence of flame but vapors do not burn. On the other hand beyond this flash point temperature if you continue to heat the bitumen the vapor start igniting after certain temperature in the presence of flame and continue to burn. The temperature at which the vapor starts igniting and then starting to burn is known as the fire point.

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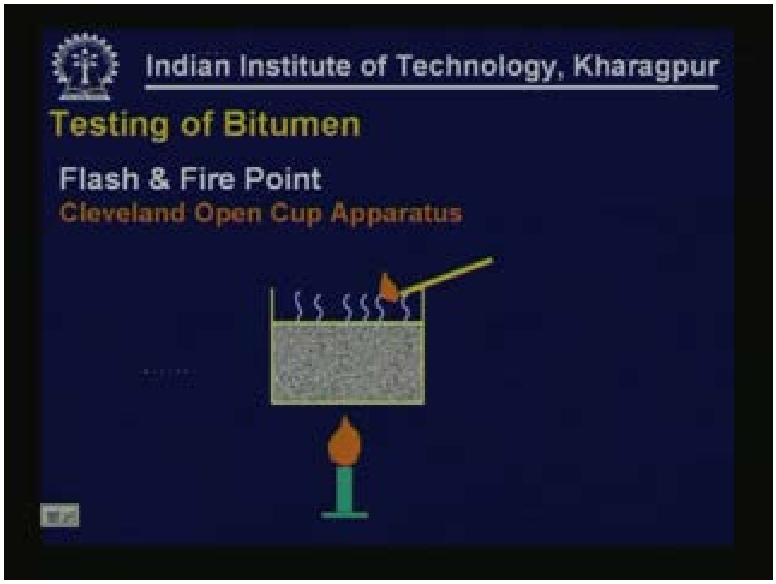

In this the commonly used test method is a Cleveland Open Cup the COC apparatus method. In this method the bitumen is heated gradually as the vapors come, fire is put to that and then if you can observe a flash that is flash point temperature and the temperature at which the vapors start catching fire is the fire point temperature.

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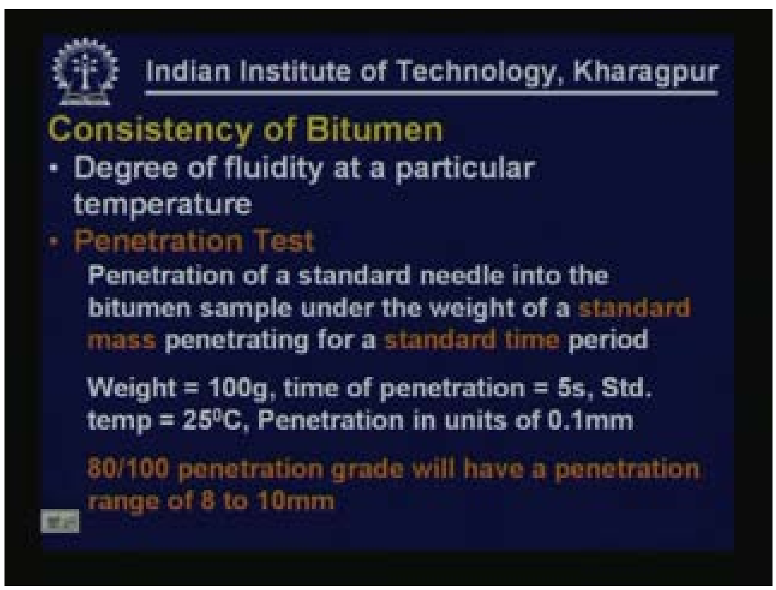

To understand the consistency or fluidity of bitumen at different temperatures there are number of tests that can be conducted. Consistency is nothing but the degree of fluidity at a particular temperature. Penetration test is the simplest that is conducted in which we determine the penetration of a standard needle into the bitumen under the weight of a standard mass and the needle penetrates for a standard time period. The standard conditions are weight including needle and other weights that we attach which is 100g, standard time is 5s and standard temperatures normally used is 25 degree centigrade. We can of course conduct this penetration temperature at different other temperatures also. The penetration is expressed in terms of 0.1mm. For example 80, 100, penetration grade bitumen where the bitumen is represented in terms of its penetration range can have penetration ranging from 8 to 10mm.

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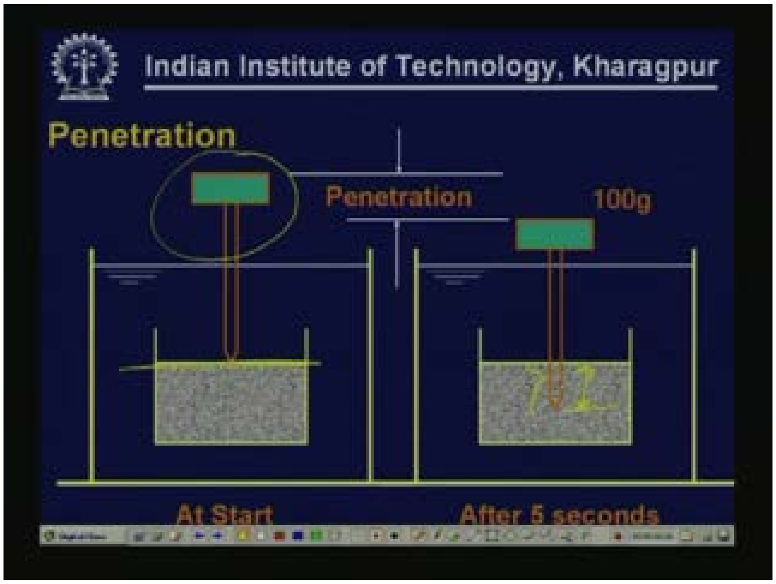

This is the simple schematic arrangement of penetration test. On the left hand side which is at the beginning of the test the needle just touches the surface of the binder and this is the mass including weight of needle (Refer Slide Time: 36:40) and after 5 seconds the needle penetrates into the bitumen, so this is what we are trying to measure and this is the penetration at this temperature.

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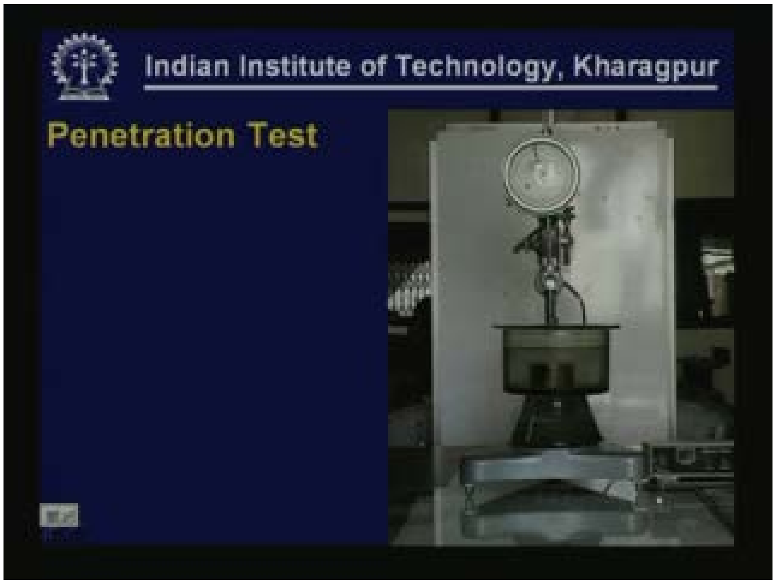

This is a simple apparatus that can be used for conduction penetration test. There is a dial which indicates the penetration.

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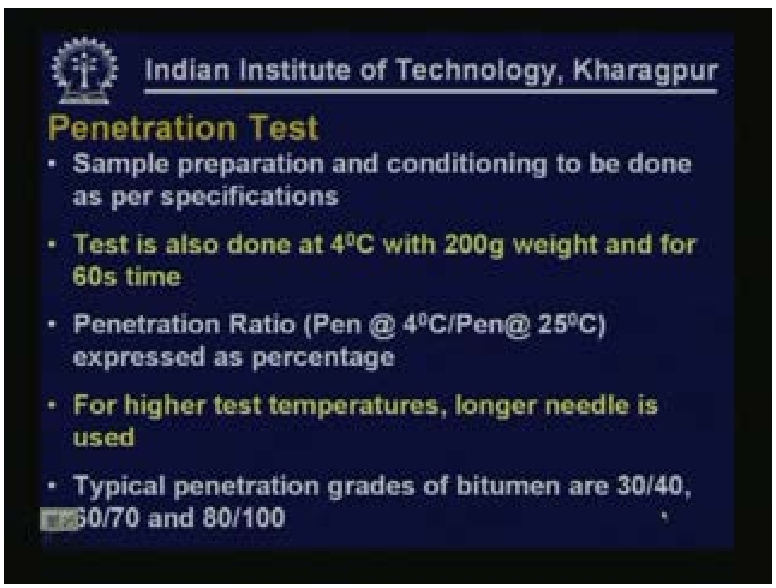

The sample has to be prepared and conditioned in water so that it attains a standard temperature of 25 degree centigrade. There are specifications available for carrying out this test. The test can also be conducted at 4 degree centigrade but with much heavier weight which is 200g and for longer time period which is 60s time. And the penetration ratio which is the penetration at 4 degrees divided by penetration at 25 degree centigrade expressed as percentage is often used to express the temperature susceptibility of the binder with variation in temperature. For higher test temperatures obviously we need to use longer needles, bigger cups and the typical penetration grades of bitumens that we normally use are 30, 40, 60, 70 and 80, 100.

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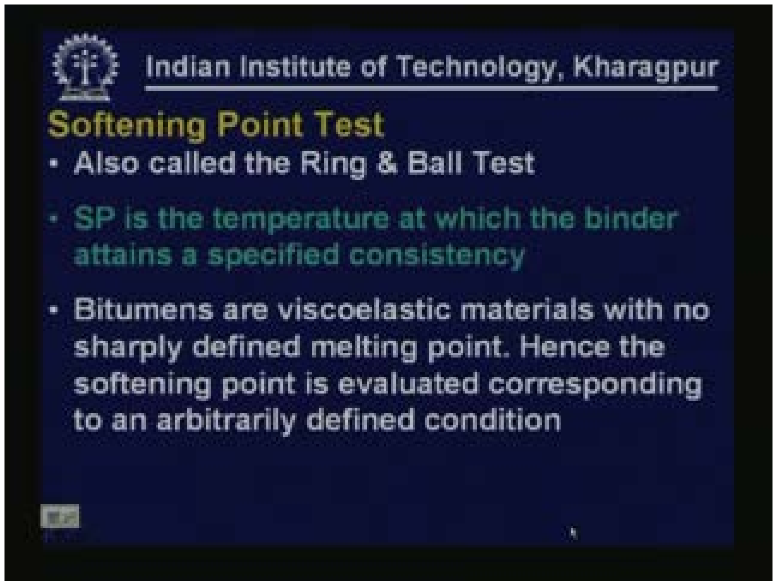

Another very important is that is conducted on bituminous binder is softening point test which is also called as ring and ball test. Softening point is the temperature at which the binder attains a specified consistency. As we know bitumens are visco-elastic materials with no sharply divided melting point. Hence the softening point is evaluated to corresponding to an arbitrarily defined condition. In the next slide let us see what this defined condition is.

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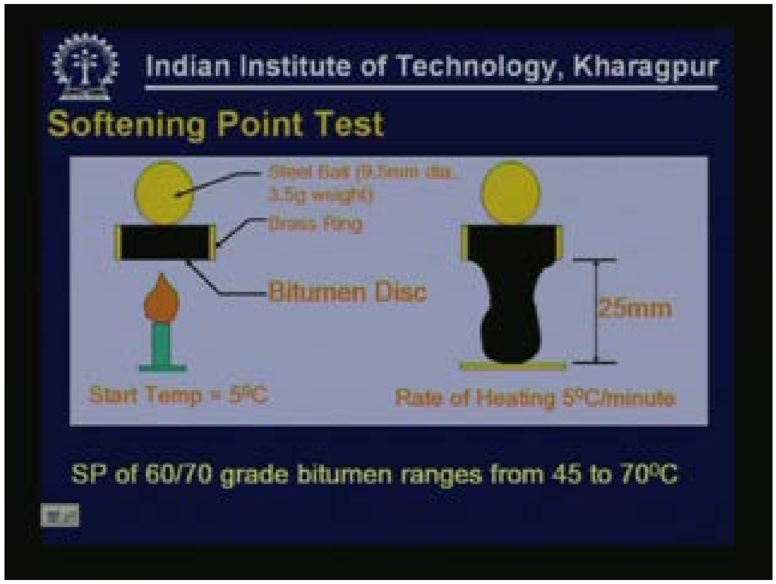

What is done in this case is a bitumen disc is formed by pouring bitumen in this ring and then it is subjected to very low temperatures so that it becomes hard and then we put a steel ball over the bituminous disc and we start heating it from an initial temperature of 5 degree centigrade. So, the ball starts moving down as the bitumen becomes softer and once the ball moves by a distance of about 25mm the temperature attained at that point is the softening point of bitumen. Here this is the condition of consistency that we are talking about and (Refer Slide Time: 39:17) here the rate of heating is at 5 degrees per minute. Typically the softening point of a 60, 70 grade bitumen ranges from about 45 to 70 degree centigrade.

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This is a typical arrangement that can be used. Of course I am not showing the complete heating arrangement and other things. We have the frame and we also have the rings and balls are shown on the left hand side.

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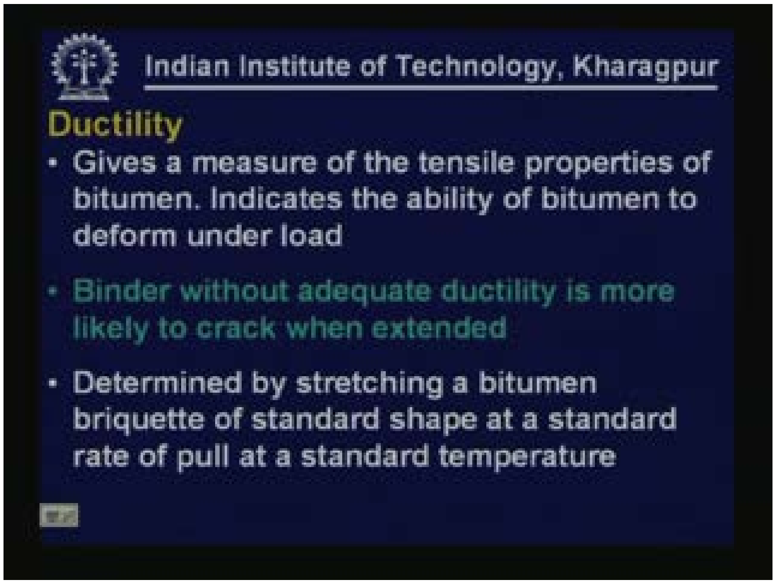

Ductility is another useful test that is conducted on bituminous binders which gives a measure of the tensile properties of the bitumen. This indicates the ability of bitumen to deform when it is subjected to load. If the binder doesn't have adequate ductility it is more likely to crack when extended because bituminous binders when they are flexed in thin films they are going to a flexed, and going to be elongated. if it is not capable of being elongated sufficiently it is going to crack. So this is the test that tests how long the bitumen can be extended or elongated before it cracks. Therefore this property is determined by stretching a bitumen briquette of standard shape at a standard rate of pull and at a standard temperature.

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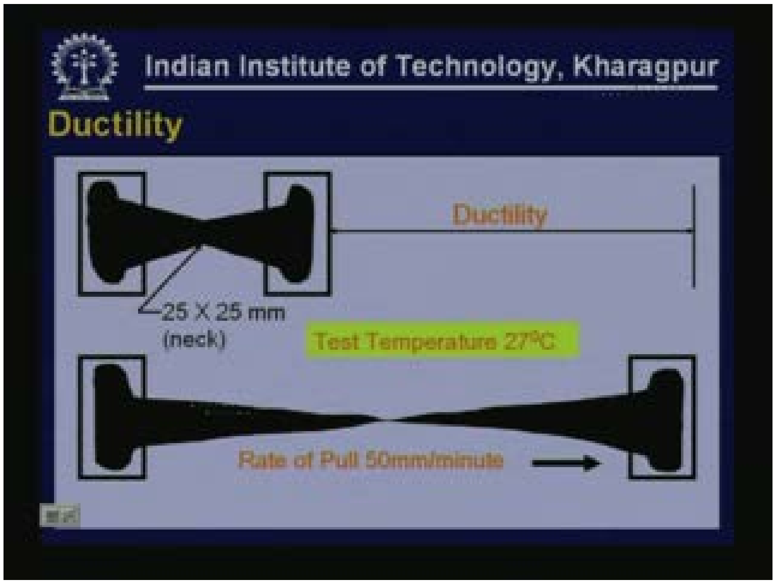

This is the standard briquette that we use having a minimum size of 25/25 at its neck and this is extended at a rate of 50mm per minute. Normally the test is conducted at 27 degree centigrade so the briquette is extended at this rate and when the thread breaks we measure the distance by which it has been extended and that is the ductility of the bitumen.

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This is a typical ductility operator that we have. On the left hand side we have the briquette. You can see it is in a dumb bell shape having a minimum cross section at the centre and on the right hand side we have an arrangement which can be used to pull this or elongate the bitumen briquette.

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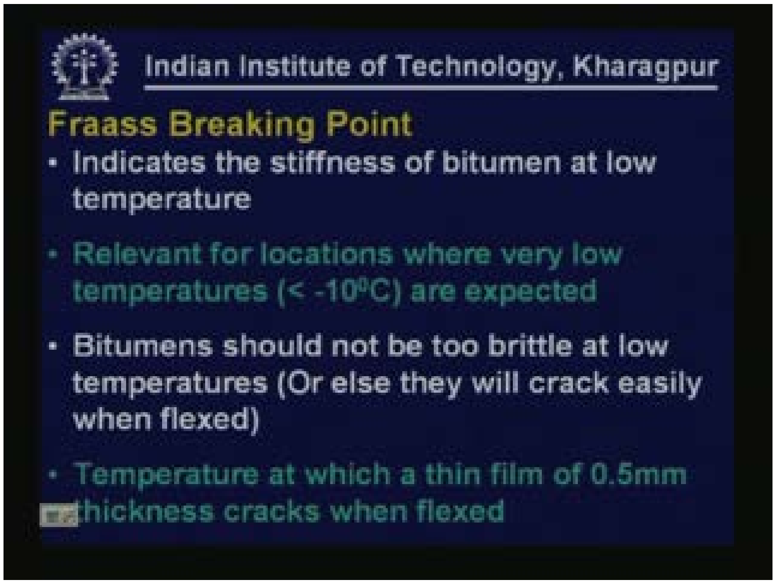

There is a Fraass breaking point test that is normally conducted on bitumen. Although it is not very useful for all climatic conditions this is relevant for climatic conditions where we can get low temperatures as low as may be –10, –15 and –20. This indicates the stiffness of bitumen at very low temperatures. As I indicated this is relevant for only those locations having very low temperatures obviously in winter season. The bitumen should not be too brittle at low temperatures otherwise when they are flexed or pulled then it will crack very easily. That is what is known as low temperature cracking. The temperature at which a thin film of 0.5mm thick bitumen cracks when flexed that is what is known as Fraass breaking point, this is a temperature.

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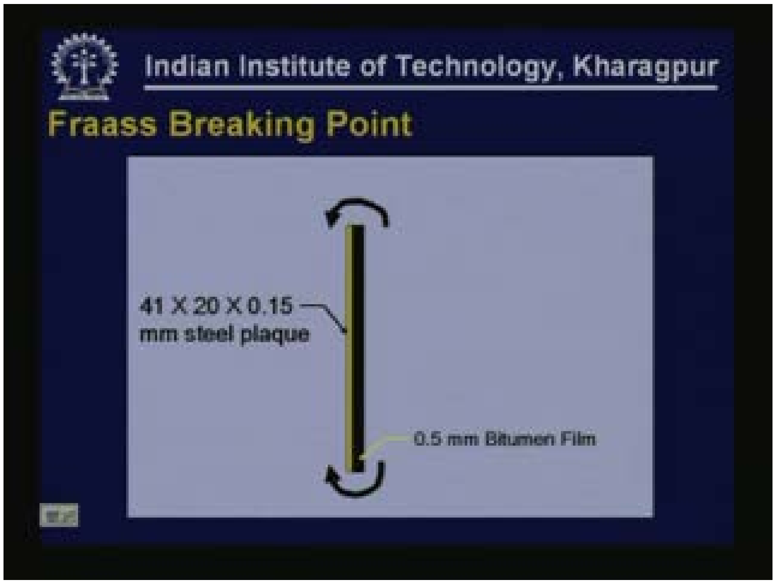

Typically what is done is there is a steel plate on which the bitumen is coated, 0.5mm bituminous film is coated on the steel plate and the temperature of the bitumen is gradually reduced to very low temperatures and then we keep on flexing the bitumen. The temperature at which the bitumen film gets cracked is the Fraass breaking point temperature.

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And the most important property that we need to study about bitumen is its viscosity. Bitumen tells us about its fundamental and rheological behavior. Rheology is the study of flow and deformation of materials. Viscosity gives us an idea about the rheology of bitumens. Viscosity as we have studied in other subjects is the resistance offered by a fluid to a shearing force which is opposite of fluidity. It is necessary to learn about the flow and deformation of bitumen binders at different temperatures corresponding to construction and also service temperatures.

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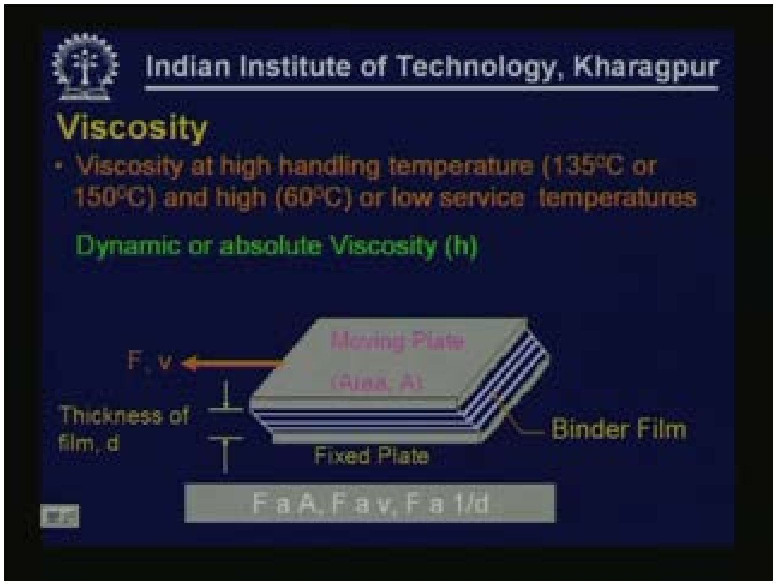

Viscosity at high handling temperatures that is at 135 degree centigrade and 150 degree centigrade and at high service temperatures typically at 60 degree centigrade is of interest for us. We are of course also interested in the viscosity that bitumen attains at low service temperatures. Low service temperatures can be as low as –10 or 15. The dynamic or absolute viscosity is defined as given below:

What we see here (Refer Slide time: 44:42) are two parallel plates, one of the plate is fixed. there is a bitumen film that is sandwiched between these two plates, the bottom plate is fixed, the top plate is moved at a constant speed of velocity of v, the shearing force that is required to move the top plate at a constant velocity of v is let's say 'f'. let us say the thickness of film is 'd' and the area of binder film is let's say A so the force required to move the top plate at a velocity of v is proportional to area, it is proportional to the velocity and it is proportional to, this should be proportional and it is inversely proportional to the distance rather the thickness of this film.

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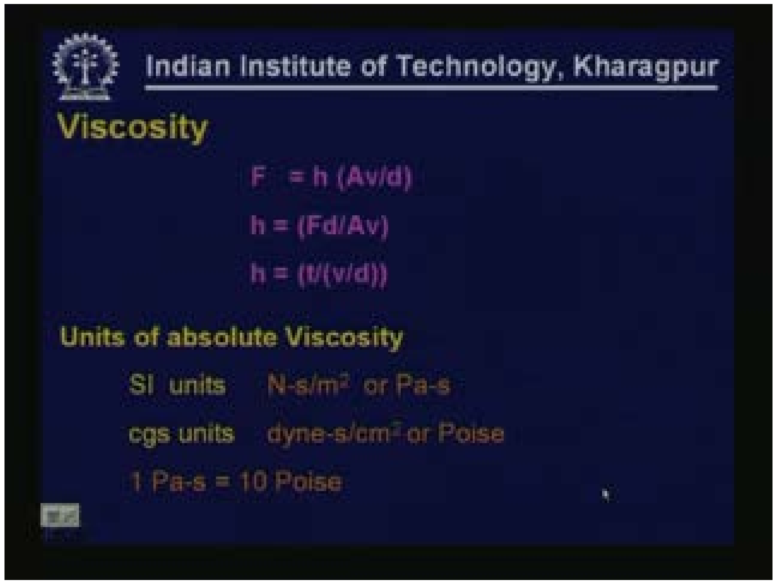

From this we get viscosity or the shearing force using a constant of proportionality where this is the viscosity. Thus by rearranging these terms we can get viscosity which is absolutely a dynamic viscosity as the shearing force multiplied by thickness of film divided by the area of the film and velocity at which the film is as the top plate is moved, f/a is the shear stress and v/d is the velocity gradient within the film thickness. The units of absolute viscosity in SI units are Newton second per meter square or Pascal seconds. In cgs units it is in Poise. And 1 Pascal second is approximately equal to 10 Poise.

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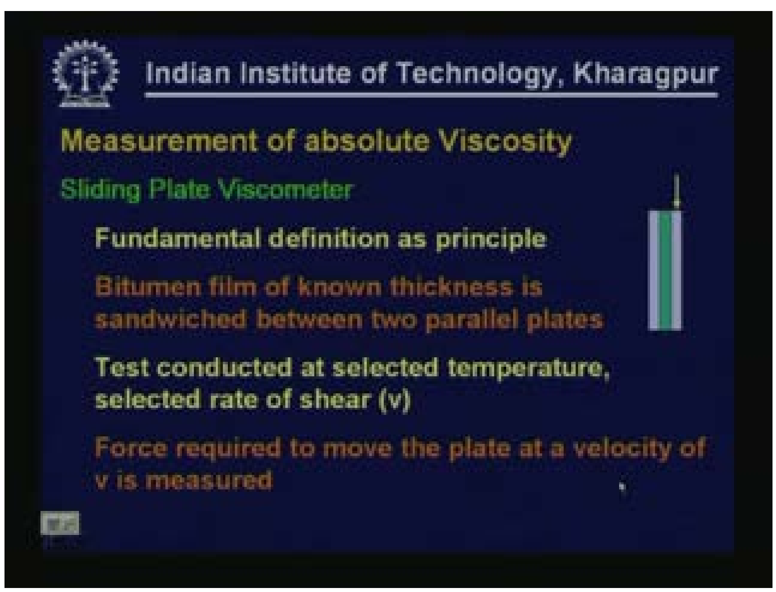

Measurement of absolute viscosity we normally use what is known as the sliding plate viscometer which operates on the basis of the fundamental principle of the definition of absolute viscosity. In this bitumen film of known thickness is sandwiched between two parallel plates. The test is conducted at a selected temperature and at a selected rate of shear that's velocity, and the force required to move the plate at a velocity of v is measured.

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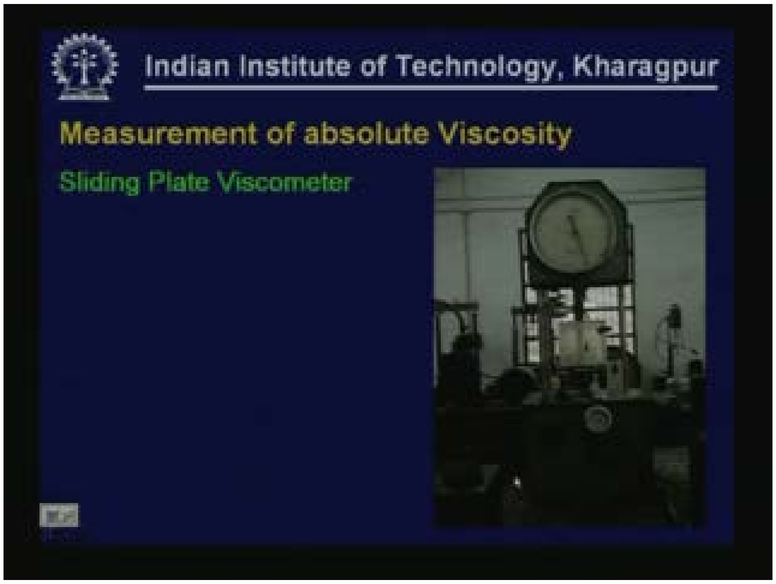

This is a typical set up used for determining the absolute viscosity using a sliding plate viscometer.

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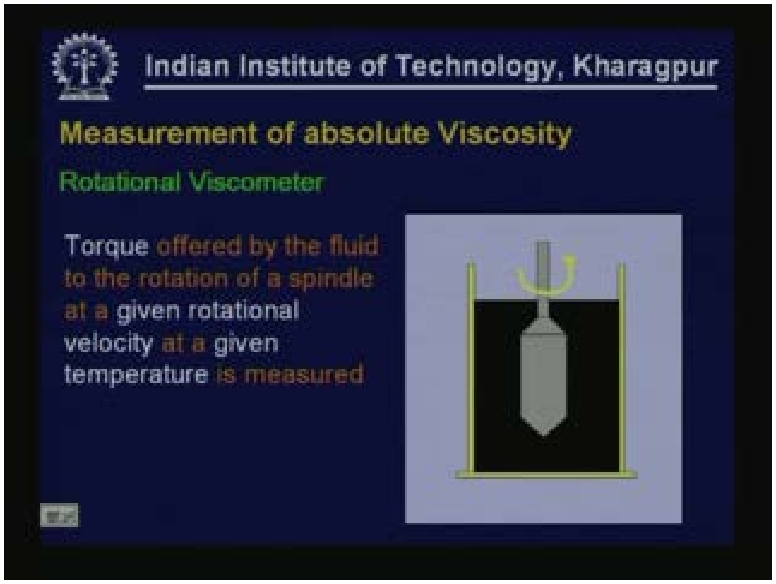

But more commonly used viscometer that is being nowadays used is a rotational viscometer. In this the absolute viscosity is obtained by measuring the torque offered by the fluid to the rotation of a spindle at a given rotational velocity at a given temperature and this has to be measured. Once you measure this torque you can calculate the absolute viscosity of this bitumen.

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This is a Brookfield viscometer, a photograph of Brookfields viscometer which is a rotational viscometer which is most commonly used nowadays for determining the absolute viscosity.

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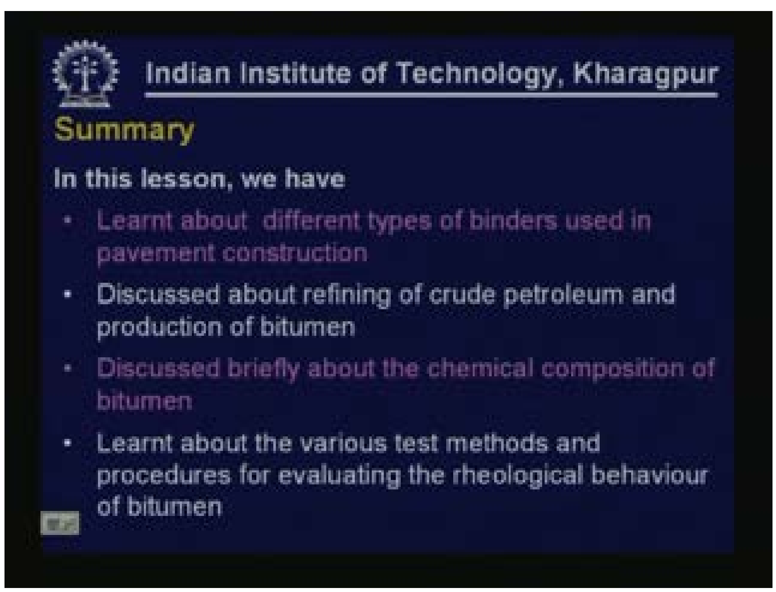

To summarize; in this lesson we have learnt about different types of bitumens or binders used in pavement construction. Although we have not discussed about all those types of bitumens we have listed bitumen, tar, cutbacks, emulsions and modified bitumens but in this lesson we have only discussed about bitumen. We also talked about tar but since tar is not going to be extensively used any more for pavement construction our discussion of tar is not going to be there any further so we are going to talk about bituminous binders only.

And in today's class we have talked about only certain properties of bitumen and we are going to be continuing in the next lesson about other properties of bitumen. We have also discussed about the process of the refining of crude petroleum and the production of bitumen from this refining process. We have discussed about the chemical composition of bitumen and we have also learnt about various test methods and procedures for evaluating the rheological behavior of bitumen. I said we have not talked about the complete testing process of bitumen but there are other methods or aspects of bitumen that we are going to be discussing in the next few lessons.

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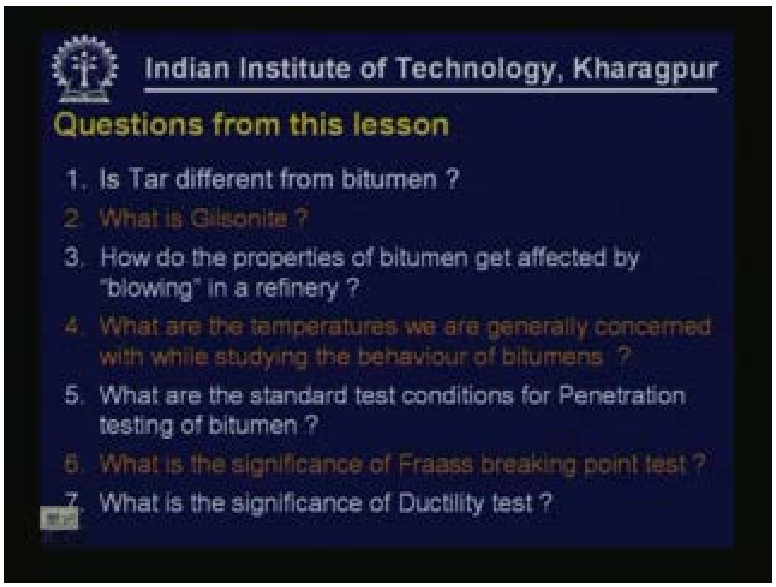

Let us take up a few questions from this lesson.
Is tar different from bitumen?
What is gilsonite?
How do the properties of bitumen get affected by the process of blowing in refinery?
What are the temperatures we are normally concerned with while studying the behavior of bitumens?
What are the standard test conditions for penetration testing of bitumen?
These standard test conditions I am not referring to the conditioning of binder before we actually conduct the test but what are the actual testing conditions?
What is the significant of Fraass breaking point test and what is the significance of ductility test?

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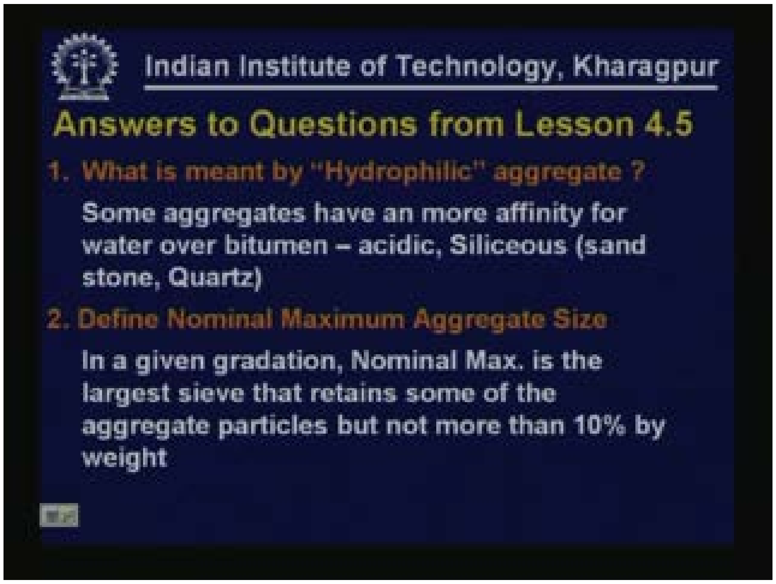

Now let us have some answers for the questions that we asked in lesson 4.5.
If your remember lesson 4.5 was about aggregates.
What is meant by hydrophilic aggregate?
As we have discussed in the last class some aggregates have more affinity to water compared to its affinity to bitumen. These are called as hydrophilic or water loving bitumens or rather water loving aggregates. Usually these are acidic in nature; these are normally siliceous aggregates typical examples being sandstone and quartz. If you have aggregates that are hydrophilic in nature these are problematic as far as stripping of aggregates is concerned because they love water more than their love for bitumen. As a result it would be easier for water to replace bitumen from this aggregate and then cause stripping.

The next question was, define nominal maximum aggregate size.

For a given gradation nominal maximum size is the largest size of the sieve that retains some of the aggregate particles but the retained portion is not going to be more than 10% by weight.

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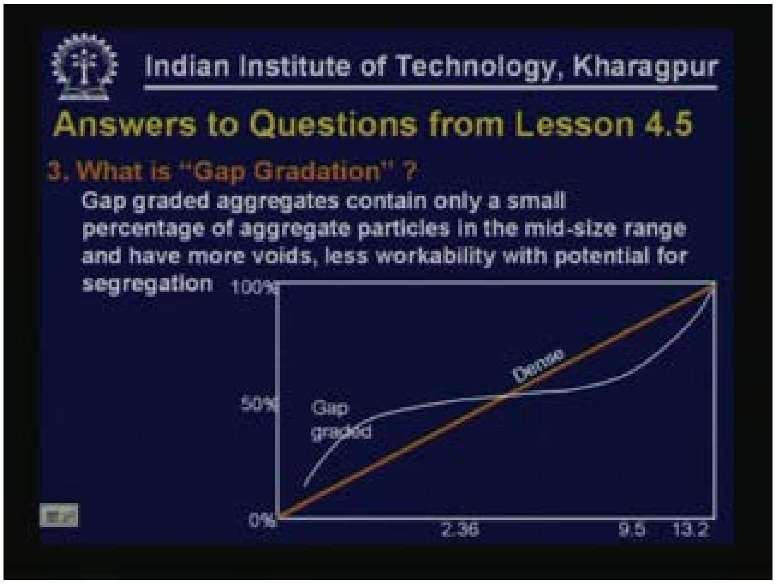

The next question was gap gradation.

Gap graded aggregates normally contain only a small percentage of aggregates in the mid size ranges. As you can see from this sketch in the mid size of range the percentage passing is more or less constant. That means those fractions are more or less missing. What we have more is the smaller fractions and the larger fractions. As a result these aggregates have more air voids, they are usually less workable and they usually have the potential for segregation. That means the larger particles will come to one place the smaller particles will go to another place so they will not be uniform mixture of all sizes throughout the medium.

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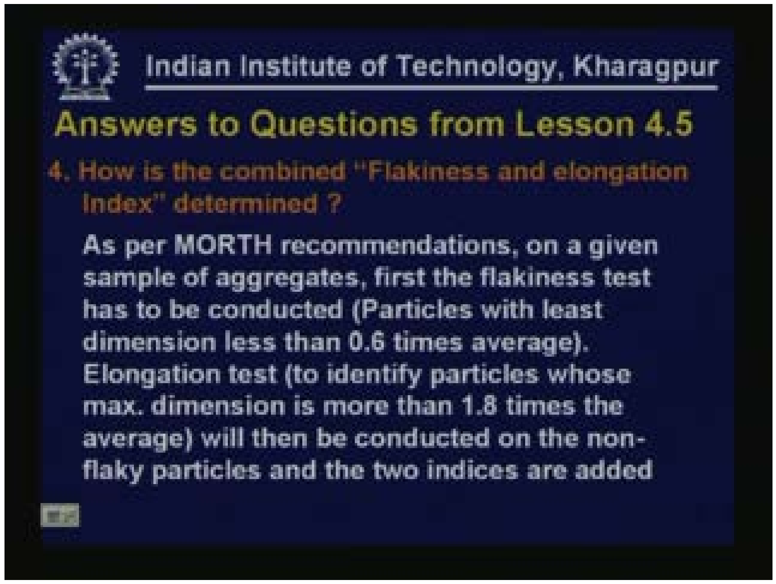

The fourth question was how is the combined flakiness and elongation index determined?
As per the MORTH recommendations we know how flakiness test and then elongation test is to be conducted. Flakiness is determining the percentage of particles with least dimension less than 0.6 times the average dimension of a particular fraction. This we have discussed earlier. Similarly elongation is identification of particles whose maximum dimension is more than 1.8 times the average dimension of a given fraction. As per MORTH recommendations what we have do is we have to first conduct the flakiness test then collect the non-flaky aggregates then we have conduct the elongation test on those non-flaky aggregates then we have to add the two indices. That is the combined flakiness and elongation indices.

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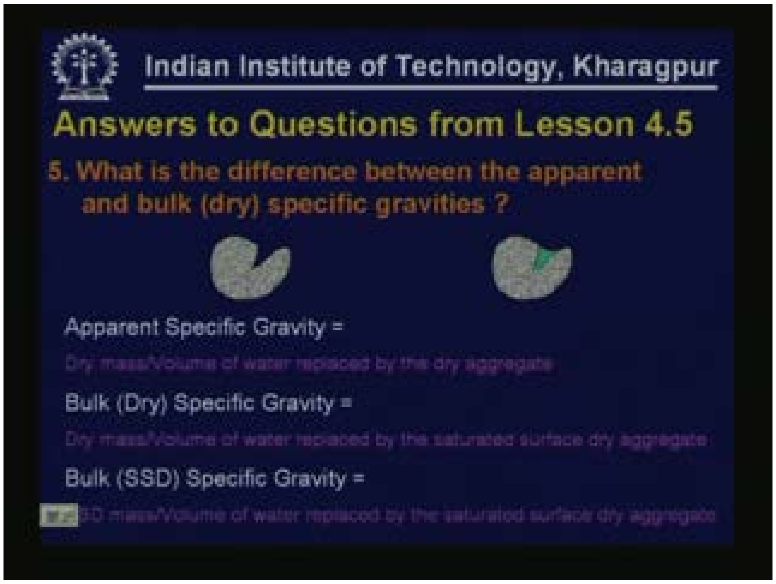

The fifth question is what is the difference between the apparent and then bulk dry specific gravity. In fact we wanted to know about dry specific gravity only. If you look at these two sketches (Refer Slide Time: 54:27) the left side aggregate is a dry aggregate without any moisture, there is a pore on the surface but there is no moisture there. On the right hand side we have the same aggregate but the pore is filled with water. To calculate apparent specific gravity we use dry mass.

In fact we use dry mass in both cases both for apparent specific gravity and bulk dry specific gravity but what is different is the volume that we use for calculation. The volume of water replaced by dry aggregate, in fact this is the volume excluding the volume of the pore that is there on the surface. If you determine this that will give us apparent specific gravity whereas for calculation of dry bulk specific gravity we have to include the volume of the pores that are there in the surface that can be penetrated by water. So, if you include that volume also that becomes the bulk volume then we get bulk dry specific gravity. But we can also get bulk saturated surface dry specific gravity wherein the volume is similar to bulk dry specific gravity but it has a saturated surface dry mass wherein it is a saturated aggregate where the surface water is removed as what we have here. This was the last question, thank you.