Introduction to Transportation Engineering
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Lecture - 31
Pavement Materials - V

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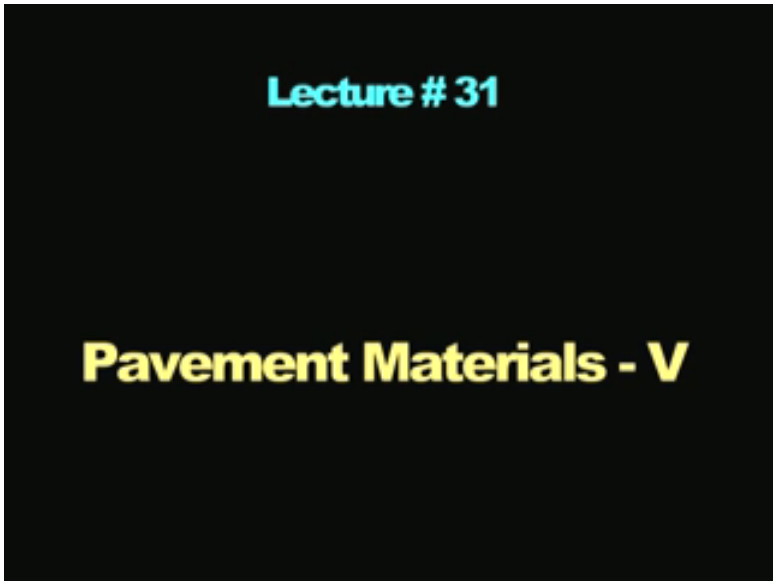

Hello viewers welcome to lesson 4.8 which is on bituminous binders which is the fifth in the series of lectures on pavement materials. These are all part of pavement design module which is module IV.

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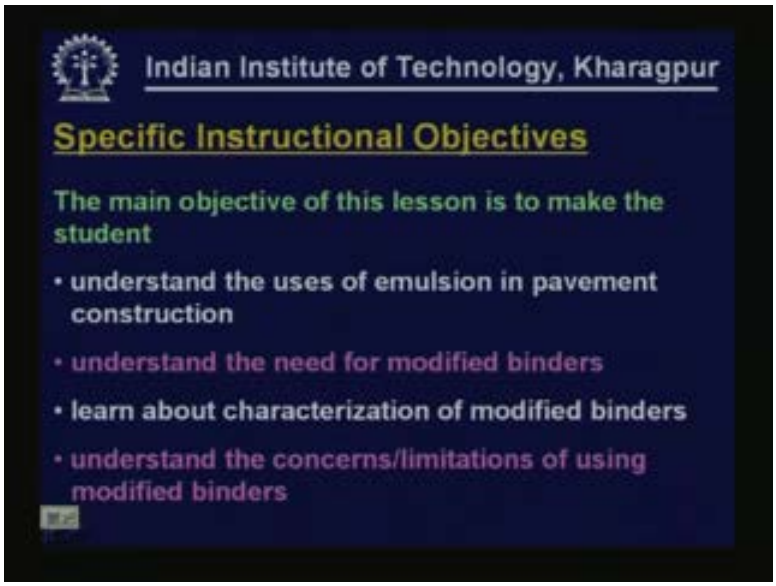

The specific objectives of this lesson are to make the student understand the uses of emulsion in pavement construction because in the previous two lessons on bituminous binders we have discussed about different types of binders that is straightened bitumen, cutbacks, different tests that can be conducted on bituminous binders and some related parameters like aging concept of bitumens, temperature susceptibility of bitumen and some fundamental properties of bitumen.

In this lesson we will cover another type of bituminous binder that is emulsion, its uses in pavement construction and we will also understand the need for using modified binders in pavement construction, learn how to characterize modified binders, how is the characterization different from that of other binders and we will also try to understand the concerns or limitations of using modified binders in pavement construction because of specific problems that can be there because of modified binders.

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We will start with bitumen emulsions.

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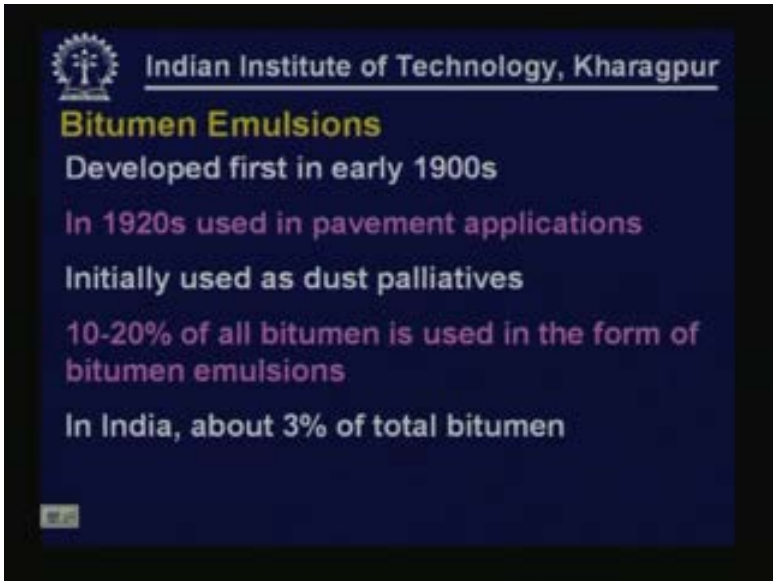

This has been developed first in the early 1900s. In 1920s emulsions were used in pavement applications. That was almost the first known application of emulsion in pavement application and these were initially used as dust palliatives to control dust problems. About 10 to 20% of all bitumen is used in the form of bitumen emulsions that's the world average whereas in India we are using about 3% of the total bitumen that is produced or rather that is used.

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The main applications of emulsions are in surface treatments which are in the form of sealing the surface or micro surfacing the pavement surface and so on. Also, in recycling if we are trying to reuse the existing bituminous layer as it has become old or it has become distressed, cracks and other forms are there so that material is removed and reused. Before it is reused emulsion can be added to rejuvenate that material and then that would form a new bituminous binder. Hence that phenomenon or that process is called as cold in place recycling so emulsions are used in recycling processes.

The other applications of emulsions include maintenance patching, application of tack coat, application of prime coat etc. These are coats that are applied over existing granular base before a new bituminous layer is applied over an existing bituminous layer before another bituminous layer is going to be applied on that so accordingly we have different types of coats that we have applied over pavement surfaces either on granular surface or on bituminous surface. If you apply it on granular surface that would be prime coat and if it is applied on bituminous surface that is tack coat.

Obviously emulsions can be used as dust palliatives. They can be used fill the cracks in bituminous layers; they can be used as protective coatings not especially for bituminous materials but also for other purposes. These are used in a construction called as surface dressing also in bituminous mixes and for soil stabilization and other proportions.

The main advantage of using bitumen emulsions is the conservation of energy and reduction in atmospheric pollution. This will appreciate once we understand what exactly emulsion is, how it is formed and how it can be used. Because with a bituminous emulsions normally we don't have to heat it so there is savings in energy, also there are no volatile matters that are coming into the atmosphere because of heating of bitumen, because of use of cutbacks. Most often emulsions replace cutback. So, as we indicated in the previous lesson cutbacks were useful but because of

the problems related to environmental aspects and also problems related with safety concerns cutback is not normally used but in its place emulsion are used. But besides replacing cutbacks emulsions can be used for various other purposes also.

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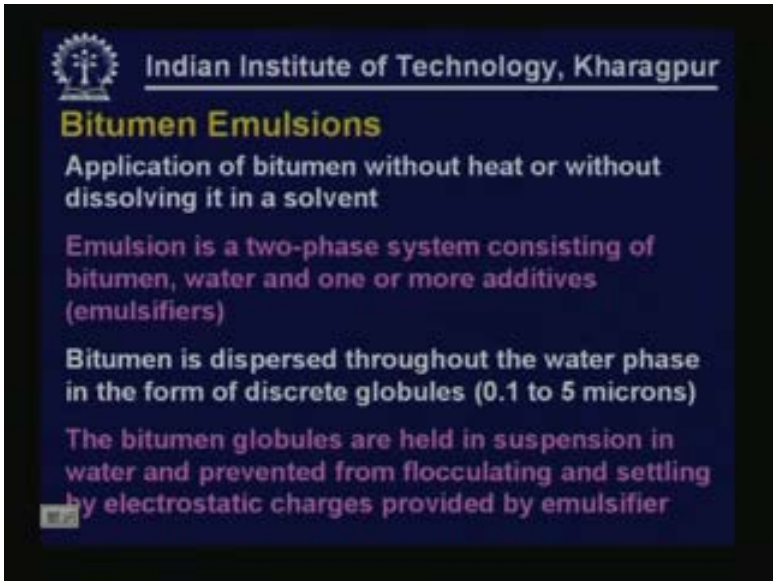

With emulsion it is possible to apply bitumen without heat and without dissolving it in a solvent. That is what we were doing in the case of cutback. In cutback we were reducing the viscosity of the bitumen by dissolving it in a solvent and thereby we are in a position to apply it to the pavement surface. So without doing that and also without applying heat in bitumen emulsions we can use emulsion without the additional need of heat or solvent.

Basically emulsion is a two-phase system consisting of bitumen and water. But it usually has one or more additives in the form of emulsifier. bitumen is dispersed throughout the water phase, basically water is the main medium, bitumen is dispersed in small particles in the form of discrete globules which are of the size 0.1 to 5 microns very small so these small globules are dispersed throughout the medium of water. The bitumen globules are held in suspension. If they don't remain in suspension we cannot use this medium. If all the globules come together and then settled down there is the separation of water from bitumen so it becomes bitumen again. So, until this is applied the globules have to be kept in suspension and free from one another. Hence these are held in suspension in water and prevented from flocculating together and settling by electrostatic charges that are provided by the emulsifiers that we used in preparing the emulsions. So, emulsifiers have got significant role in keeping the emulsions stable, keeping the bitumen globules and suspension and thereby enabling us to use it.

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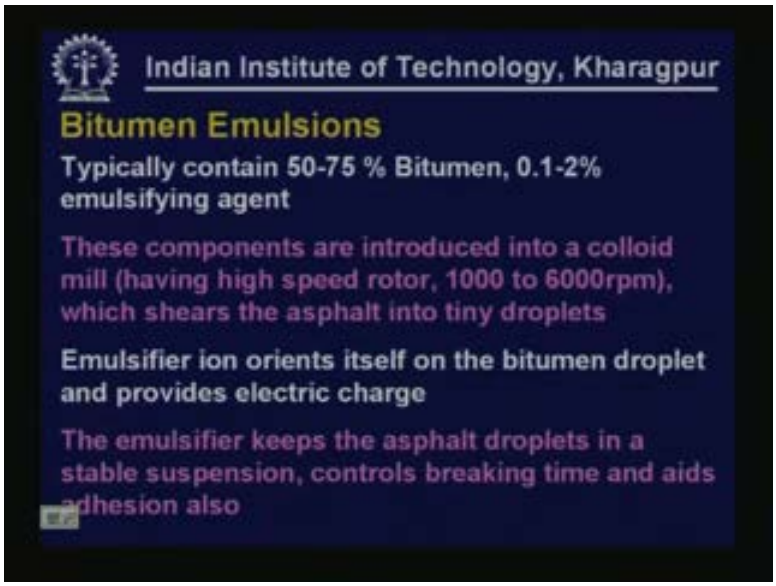

Emulsions typically contain about 50 to 75% bitumen. Ultimately this is the bitumen that we are going to actually use. This is the bitumen that we are going to use to coat aggregates, coat any surface. So all our calculations will have to be on the basis of what is the bitumen that is going to be finally available out of the emulsion because water is going to go away. So this is the bitumen that is going to be available, how much quantity is required to coat a given aggregate, given surface so the corresponding quantity of emulsion has to be used. And it may also have about point one to two percent emulsifying agent, obviously the rest is water.

These components are for producing emulsion. These components are introduced into a colloid mill which operates at a very high speed, there is a high speed rotor and the operating speed could be thousand to 6000 rpm which shears the asphalt into tiny, very small droplets. Emulsifier ions orient themselves on to the bitumen droplet and then it provides electrical charge. It can be positive charge or negative charge depending on the emulsifier that we use. So the bitumen globules get some electrical charge because of the emulsifier and that is what keeps them in suspension. So the emulsifier keeps the asphalt droplets in a stable suspension. The emulsifier also controls the breaking time, we will discuss what breaking time is and also aids in adhesion of the bitumen to aggregates or pavement surface.

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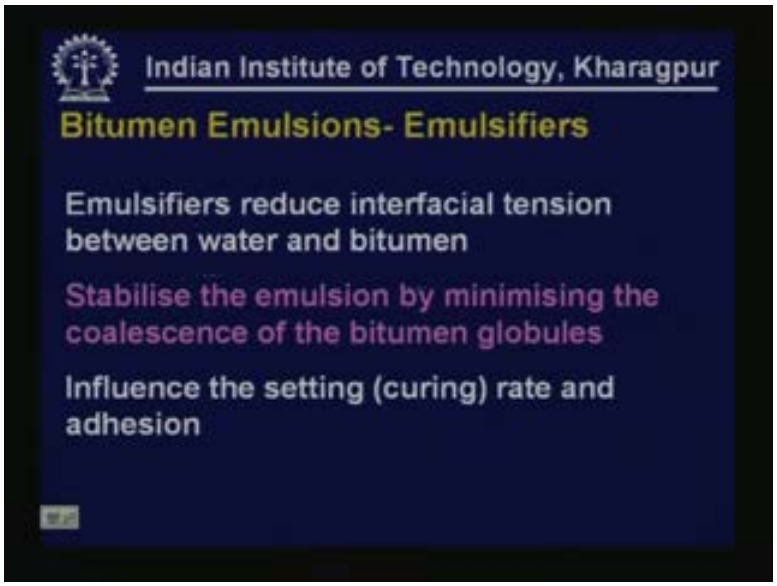

The emulsifiers reduce the interfacial tension between water and bitumen and they stabilize the emulsion by minimizing the coalescence of bitumen globules, this is what we discussed in the previous slide and the emulsifiers that we select influence the setting or also known as curing rate and adhesion.

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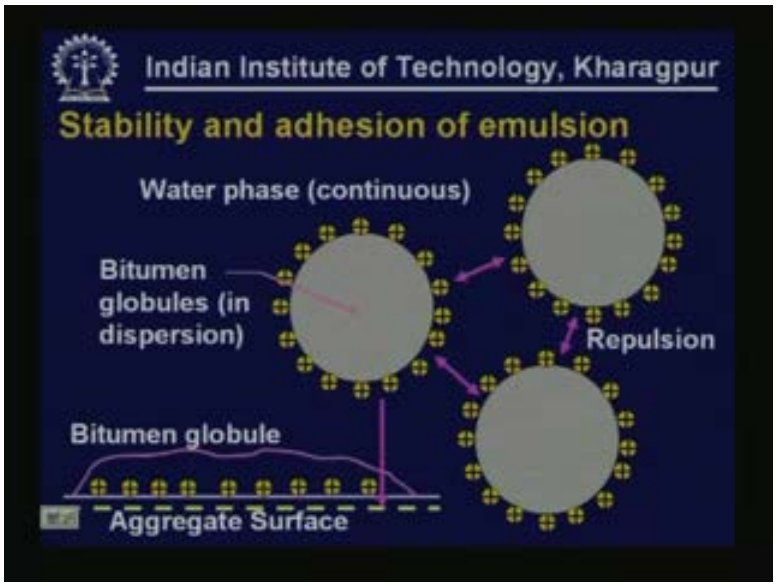

Typically the emulsion can be represented in a pictorial manner in this way. If the entire thing can be considered to be water phase we have bitumen globules although they have shown in a very large and exaggerated manner here and on these globules we have emulsifier adherent on to

it and then providing charge. In this case it has got positive charge so there is positive surface charge for all these bitumen globules. So obviously in this case the emulsifier that is used is of that type which provides positive electric charge to the bitumen globules.

As a result all this globules have got similar charge. Naturally they repulse each other so the possibility of them coming together and then coalescing or forming bigger particles is very remote or significantly less. So this is what keeps these particles in suspension because they are small particles they remain in suspension and unless they come together they don't become heavy enough to settle down. When this emulsion is used on aggregate surface having negative charge as you see here, let's say this is aggregate surface. If you have an aggregate having negatively charged surface then this is the right kind of emulsifier to be used. The emulsifier that provides positive charge to the bitumen globules is the right kind of emulsifier to be used if we are going to use the emulsifier with aggregates having negative charge.

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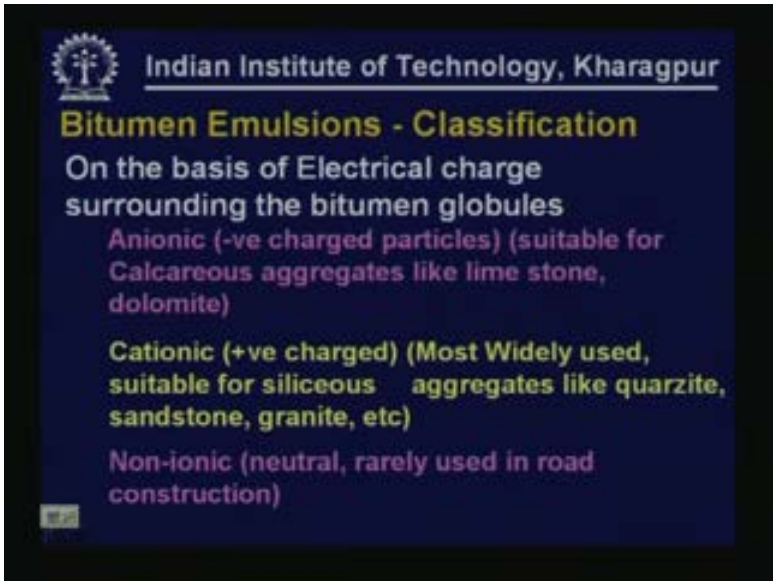

Bitumen emulsions are normally classified usually on the basis of electrical charge surrounding the bitumen globules which in turn is on the basis of the emulsifier that we use. Anionic emulsions have got negative charge particles and these are suitable for calcareous aggregates like limestone dolomite. On the other hand, cationic which are positively charged aggregates rather positively charged emulsions are most widely used. Cationic emulsion is the most commonly used emulsion in India or in many countries. These are suitable for siliceous aggregates like quartzite, sandstone, granite and so on. There are non ionic neutral emulsions also but not normally used in pavement construction.

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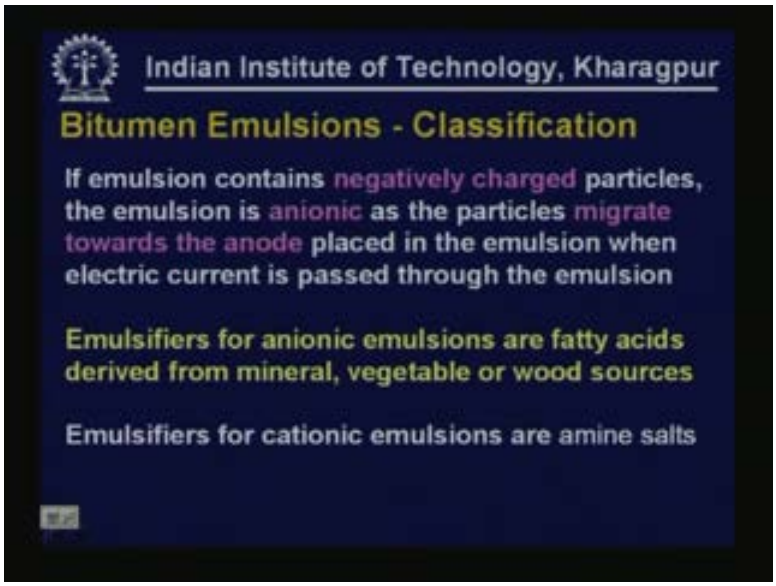

As we just indicated earlier if the emulsion contains negatively charged particles then the emulsion is anionic as particles would migrate towards the anode placed in the emulsion when electric current is passed through the emulsion. If you put electrodes in the emulsion and pass current through it the bitumen particles because of their charge will migrate towards the anode. That's why the emulsion having negatively charged particles is called as anionic emulsion. Emulsifiers for anionic emulsions are usually fatty acids derived from mineral, vegetable or wood sources whereas for cationic emulsions the commonly used emulsifiers are amine salts.

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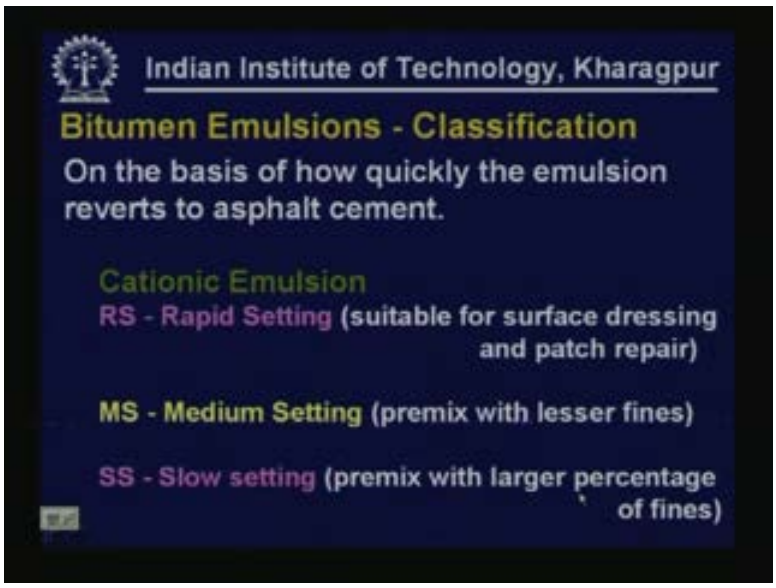

The emulsions can also be classified on the basis of how quickly the emulsion is reversed to asphalt cement. Ultimately asphalt cement ore bitumen is what we want as our binder so the water has to go away. Hence depending on the process that takes place like how quickly the water goes away and the bitumen coats the aggregates the emulsions are classified such as rapid setting, medium setting and slow setting.

Rapid setting emulsions are suitable for surface dressing and patch repairing. Medium setting emulsions are suitable for premix carpets with aggregates having lesser fines whereas slow setting emulsions are suitable for (( )) (00:16:08) purposes where we are using aggregates with larger percentage of fines. Similar things we have discussed in the case of cutbacks also. If the amount of fines is more then that will accelerate the setting process or breaking process so that will not actually permit sufficient coating of all the fine particles. If you have larger percentage of fine particles then we have to allow sufficient time for the bitumen to be coating all the fine particles so the settling, breaking or curing has to be over longer periods. That's why as the percentage of fines increased we are going for slow setting, slow curing, slow breaking type of emulsions and cutbacks.

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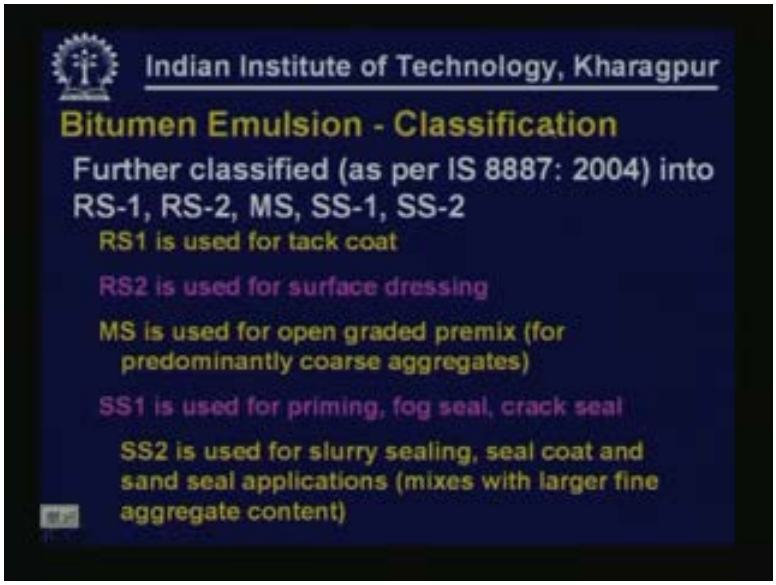

The bitumen emulsions are further classified as per Indian standard, IS: 8887 : 2004 this is the most recent version into RS-1, RS-2 rapid setting are further divide into two different groups and also slow setting are further divide into two different groups and the users are also identified. RS-1 is to be used for tack coat, RS-2 is used for surface dressing, medium setting emulsion is to be used for open graded premix having predominantly coarse aggregates. SS1 which is a slow setting variety type 1 is used for priming, fog seal and crack seal. SS2 is used for slurry sealing, seal coat and sand seal applications. These are mixes containing larger and fine aggregate contents.

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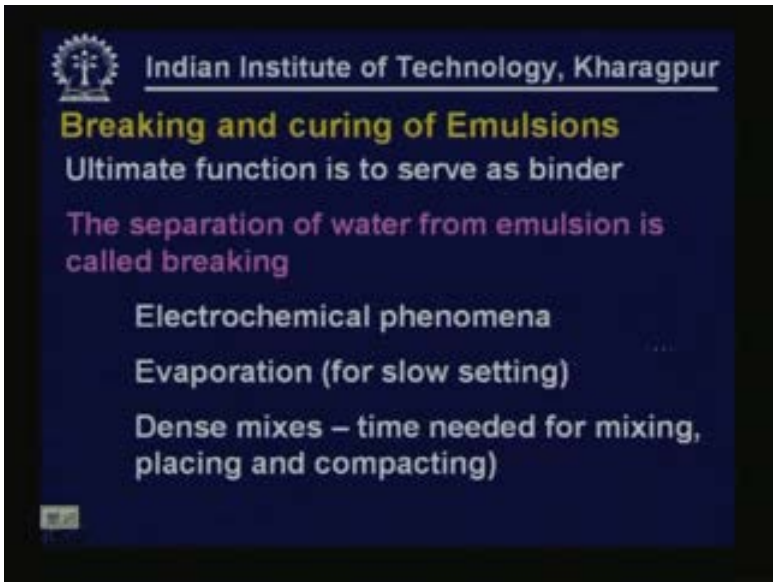

As we said ultimately we need bitumen to be left behind and water should go away. So the removal of water from emulsion is called as breaking. Breaking is a process which occurs through various phenomena. It could be electrochemical phenomena; it can be through evaporations especially for slow setting emulsion. For dense mixes the time needed for mixing, placing and compaction will also have to be assessed.

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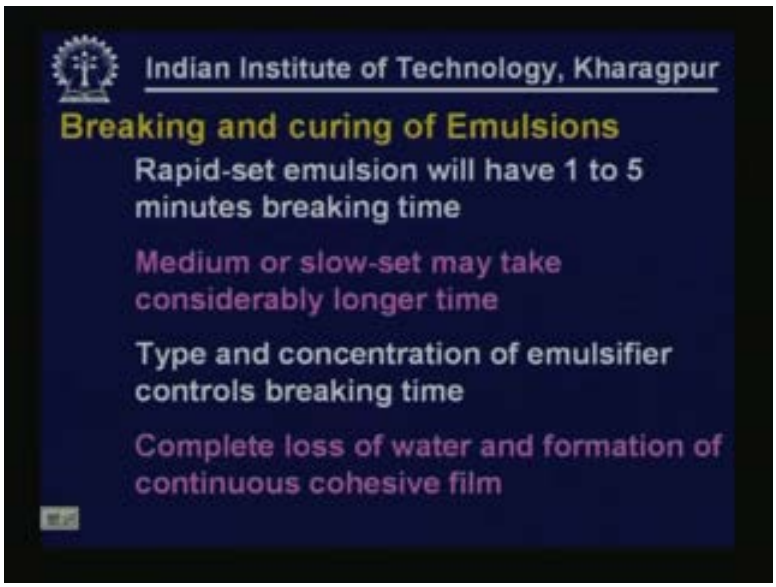

Normally rapid setting emulsions will have about 1 to 5 minutes of breaking time. So, if within 1 to 5 minutes bitumen can coat whatever surface it is suppose to coat then rapid setting emulsion

can be used. But medium and then slow setting emulsions may take considerably a longer time. We also have to find out the bitumen content that is available in the emulsion, so the type and concentration of emulsifier controls the breaking time. In fact we are referring to the type of emulsifier that is used so that also controls the breaking time. Complete loss of water and formation of continuous cohesive film is what we called as breaking.

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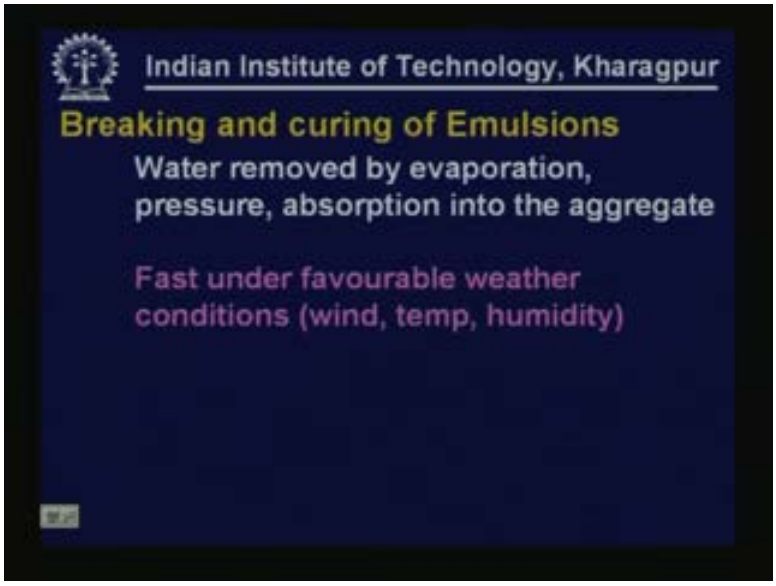

The water is normally removed by evaporation; it can be by mechanical means application of pressure, absorption into the aggregate. It normally happens faster under favorable weather conditions such as the condition that we referred to would be wind, temperature and humidity.

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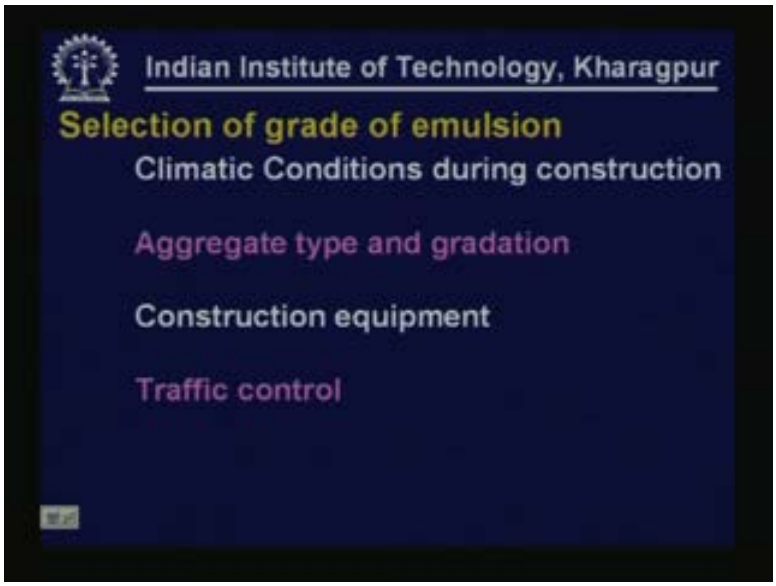

The grade of emulsion that should be selected for a given purpose depends on the climatic conditions during construction, hot climatic conditions, rainy, cold climatic conditions, accordingly what would be the rate of curing, what will be the rate of breaking and then what would be the time available before breaking occurs or curing occurs and how much time is actually required for the bitumen to be coating fine aggregates, coarse aggregate so it also depends on type of aggregates, on climatic conditions, the surface that is to be coated and depending on the thickness of the film that has to be formed, the construction equipment that we use to spray, to mix it and to roll and compact and the traffic control that can be adopted in a given situation. If the pavement has to be opened very quickly you have to go for quicker means, if you have time you can go for slower one because slow setting emulsions will always be better because they are capable of coating the aggregates or surfaces more thoroughly. So the selection of a grade of emulsion will be dependent on climatic conditions during construction, aggregate type and gradation, construction equipment to be used and the traffic control methods or flexibility that is available at a given location.

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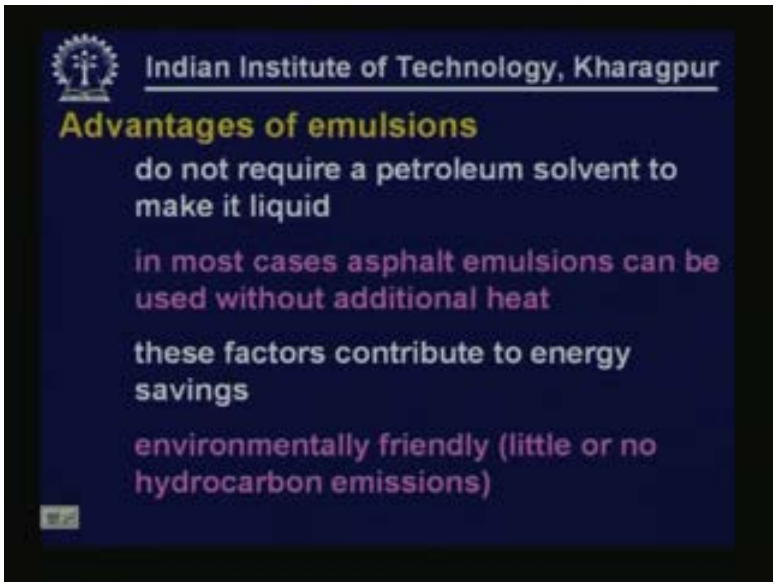

The main advantage of emulsions is, they do not require petroleum solvent to make it liquid. This is in comparison to cutbacks. In most cases asphalt emulsions can be used without additional heat. These factors contribute to energy saving because we don't have to use heat so we can save energy.

Obviously these are environmentally friendly because little or no hydrocarbon emissions are there because we are not heating bitumen and there is no emission of solvents that we have in the case of cutback so there is a little or no hydrocarbon emission. There are various tests that we normally conduct on emulsions. One of them is storage stability test to identify how stable a given emulsion is going to be when it is stored because most of the emulsions usually have certain specified shelf life.

Certain emulsions will have to be used within 24 hours, other emulsions can be used within one week, within one month, and normally the manufacturers specify the shelf life also. So the emulsion will have to be normally used within that time period otherwise the particles will coalesce and then bigger particles will form and then they all start settling down. So there is going to be separation of water and then bitumen. Then once that forms we cannot use that.

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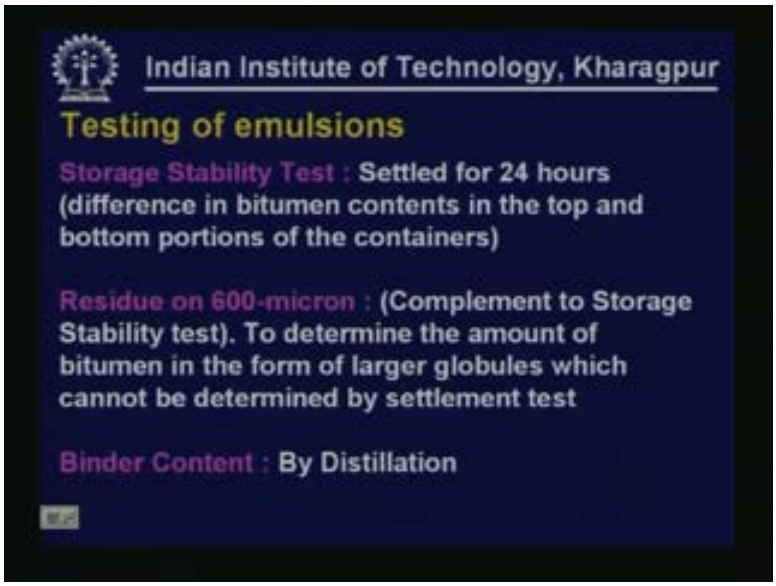

So in storage stability test what we determine is the emulsion is settle for twenty-four hours and the emulsion from top part and bottom part is obtained and the bitumen from that is obtained from the top portion and bottom portion separately, the bitumen is obtained by removing the water by distillation so the content is compared from the bitumen that is obtained from top portion and bottom portion and if there is no settlement at all absolutely you should have the same bitumen content in both top portion and bottom portion of a container after 24 hours of settling so that is what is compared.

Similarly, residue on a 600 microns sieve the emulsions will be sieved through a 600 microns sieve, we already discussed that the emulsion globules of the bitumen globules are going to be very small 5 micron or even smaller size, unless we have larger globules forming nothing should be remaining on a 600 microns sieve. So, if we sieve the emulsion through a 600 microns sieve depending upon how much quantity is retained on 600 microns sieve that will tell us the amount of coagulation or the coalescence that is taking place. We are also interested in finding out what is the proportion of percentage of bitumen in emulsion because that's what ultimately is going to be useful for us. So this can be done by distillation, removing all the water and then finding out what is the remaining bitumen.

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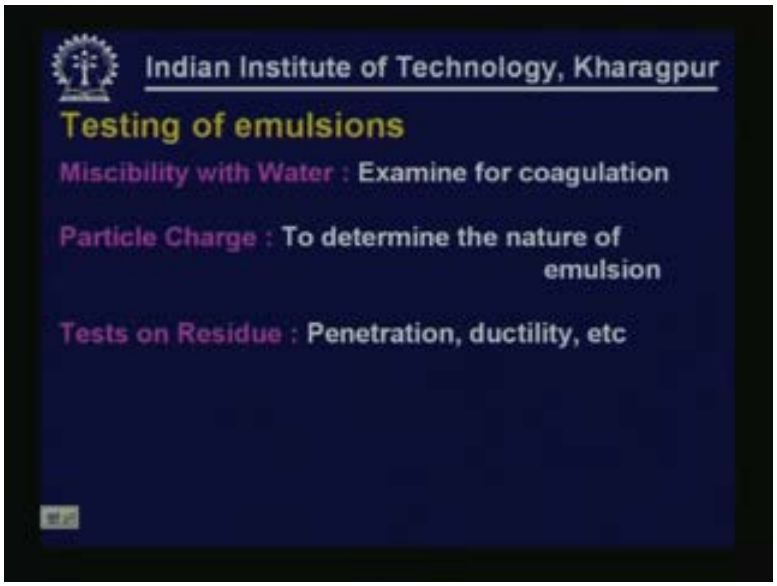

We also conduct test for examining for coagulation to find whether there is going to be any coagulation of emulsion when we add this with water, that is another test we do and we can also determinate whether a given emulsion is cationic or anionic by conducting particle charge test. This is to determine the nature of emulsion. The residue that is obtained from emulsion after distillation is a binder that is going to be used. So obviously there are number of tests we conduct on this residue like we conduct on any other bituminous binders such as penetration, ductility, softening point and so on. So there are certain tests that are prescribed for the residue that is going to be obtained from the emulsion.

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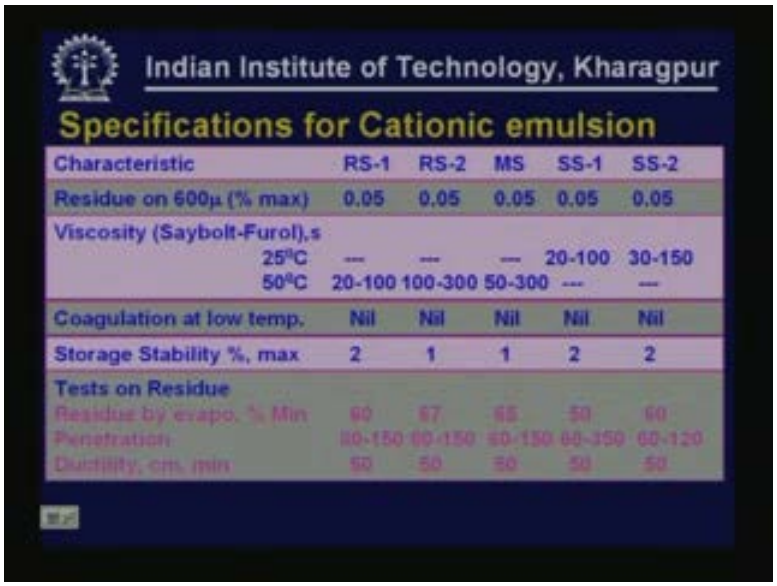

These are the typical specifications for cationic emulsion. As I indicated cationic emulsion is the mostly commonly used emulsion in India. for different types of emulsions RS1, RS2, rapid setting one, rapid setting two, medium setting, slow setting one, slow setting two the residue or the matter that is retained on 600 microns sieve should not be more than .05%.

Similarly, the viscosity determined using a Saybolt-Furol viscometer at the specified temperatures should be within the range as indicated here. There should not many coagulation at all especially at low temperatures. The maximum difference in bitumen content from top to bottom from a storage stability test should be 2%, 1%, 1%, 2, 2 for different types of emulsions and when tests are conducted on the residual bitumen the residue content should be a minimum about 60%, 67, 56 so different quantities are specified for different types of emulsions. The penetration normally can range between 80 to 150 or 60 to 150, 60 to 350 these have been specified in terms of the typically produced slow setting emulsion one, slow setting emulsion two and so on and the binder that is normally used in producing these emulsions the corresponding bitumen properties have been given here. The ductility should be a minimum of 50 for all the residual bitumen that we get from these emulsions.

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We will next discuss about modified binders.

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On majority of our roads conventional bitumens perform satisfactorily. but in special situations like highways having very high traffic intensity, highways having overloaded vehicles, airport pavements, facilities were we are going to have slow vehicles, vehicles stopping, intersections, bus stops, loading, unloading areas, parking areas where these vehicles are going to be in stationery condition for long durations are all special situations and they require special binders. Typically normal binders have not been proved to be very satisfactory, normal binders such as 80/100 binder, 60/70 binder in many cases has not been found to be satisfactory.

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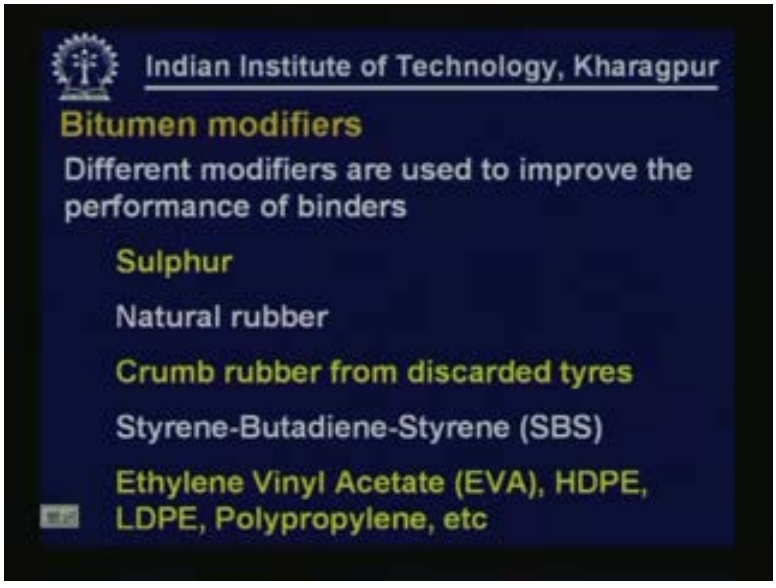

So different bitumen binders are used to or rather modifiers are used to modify the normal bitumen. Modified binders are nothing but bitumen modified by different modifiers. Various types of modifiers are available accordingly various modified binders are available. Different modified binders are used to improve the performance of binders. Certain modifiers improve certain characteristics and other modifiers improve other characteristics. So there is no one specific modifier that can be considered to be improving all aspects of bituminous performance. The various other modifiers that are used are sulphur, natural rubber, crumb rubber obtained from discarded tyre, old tyres normally when they re-treaded they are scraped and the small particles that come out of the tyres are considered as crumb rubber which is also added to bitumen to form what is known as crumb rubber modified bitumen. Various types of polymers are Styrene-Butadiene-Styrene SBS, Ethylene Vinyl Acetate EVA, high density polythene HDPE, low Density Polythene LDPE, polypropylene and there are various other types of modifiers.

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What these modifiers do to the binders? The main advantages of using these modified binders are the temperature susceptibility of modified binders is in general much lower compared to straighten bitumens. That means the properties do not change significantly with temperature variation. These binders have higher resistance to permanent deformation at higher temperatures. In fact this is the main purpose for which usually modified binders are used.

Especially in India we are concerned about failures that are occurring at higher temperatures and permanent deformation, rutting is occurring in our bituminous mixes at high temperatures. That's the reason in India mostly we are using modified binders. So high resistance to permanent deformation at higher temperatures is one aspect that we are interested in. these have better age resistance properties with age the degree of oxidation that takes place degree of change of properties with time is much lesser in case of modified binders compared to normal binders.

Similarly these binders are generally known to have better addition to aggregates. The mixes have usually higher fatigue life and there is also delay in the initialization of cracks and lesser reflective cracking problems are also there.

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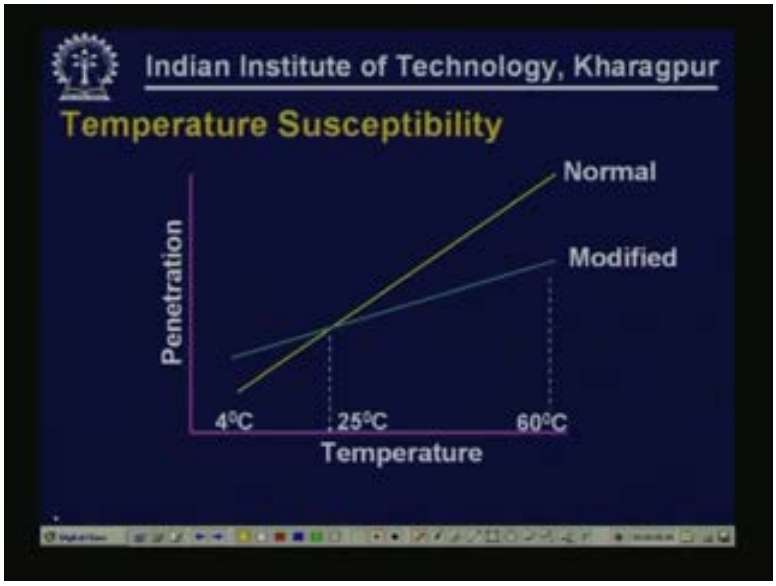

How the temperature susceptibility is going to be different in the case of modified binders can be explained using this diagram. What is presented here is the temperature versus penetration plot. The penetration on y axis should be on log scale then only we can normally expect this to be a straight line relationship. This is a line we get for normal binder and this is the corresponding line that we get for modified binder. Obviously we can see that the line for modified binder is much flatter compared to the line that we have for normal binder. So, flatter the slope we know it is less temperature susceptible because over a temperature range the corresponding change in property is going to be much smaller for modified binder.

Here is something interesting, if you examine the penetration that is obtained at twenty-five degree centigrade, and both binders let us assume have same penetration. So, if you only consider the penetration value you should assume that both binders are going to perform similarly. But consider the penetration values of both binders at higher temperature that is 60 degree centigrade whereas the normal binder has got higher penetration and the modified binder has got lower penetration. That means at higher temperature modified binder is much harder than normal binder. On the other hand at lower temperature modifier binder has got higher penetration compared to normal binder. Hence normal binder would be much stiffer at 4 degree centigrade compared to modified binder. So we want the binders to be softer, not very stiff at low temperature and they should not be very soft at higher temperature. This is the property that is normally attained by modified bitumen.

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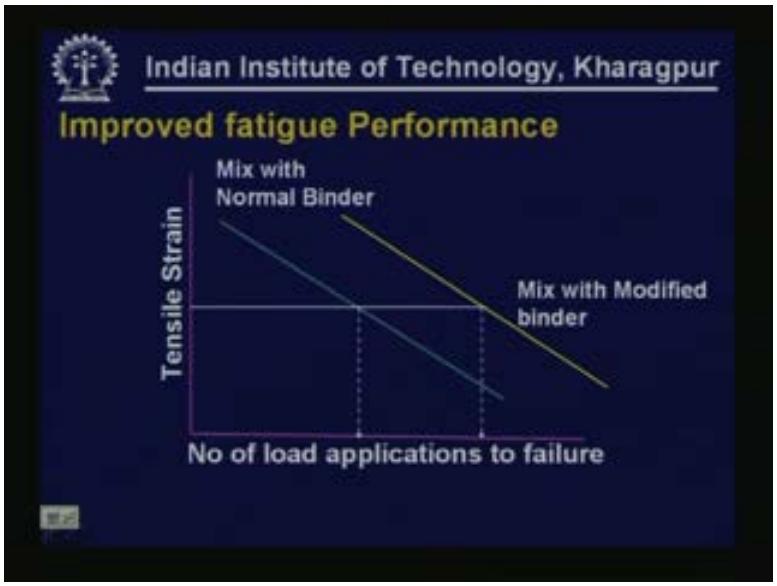

These modified binders are also normally known to improve the fatigue performance. This is illustrated in this sketch. For example, there is a bituminous pavement and for a given tensile strain which is represented on the y axis the two lines represents the behavior of the mix with normal binder and behavior of the mix with modified binder. The line on the right hand side represents the mix with the modified binder. So, for a given tensile strain the number of load applications required to cause failure is much smaller in the case of normal binder whereas it's going to be significantly larger with the use of a modified binder.

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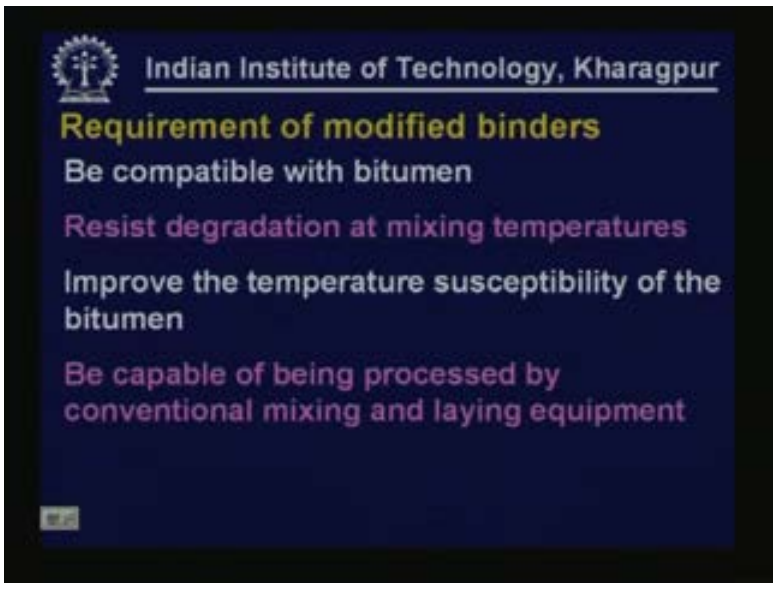

But to use modified binders there are certain requirements that have to be satisfied. The modifiers that were going to be used should be compatible with bitumen. because we blend them with bitumen but they should not get separated after certain time, during storage, after use and in various processes they should not get separated significantly so that is what is meant by compatibility with bitumen, we should be able blend them with bitumen. They should resist degradation at mixing temperatures. We should not be using modifiers which get degraded at temperatures such as 150 degree centigrade and they should improve the temperature susceptibility of the bitumen. This is the fundamental purpose or the main purpose for which we are using modifiers. They should also be capable of being processed by conventional mixing and laying equipment. Just because we are using modified binders we should not be required to use different types of equipment because simultaneously similar equipment is going to be used for constructing other layers using normal bitumens also.

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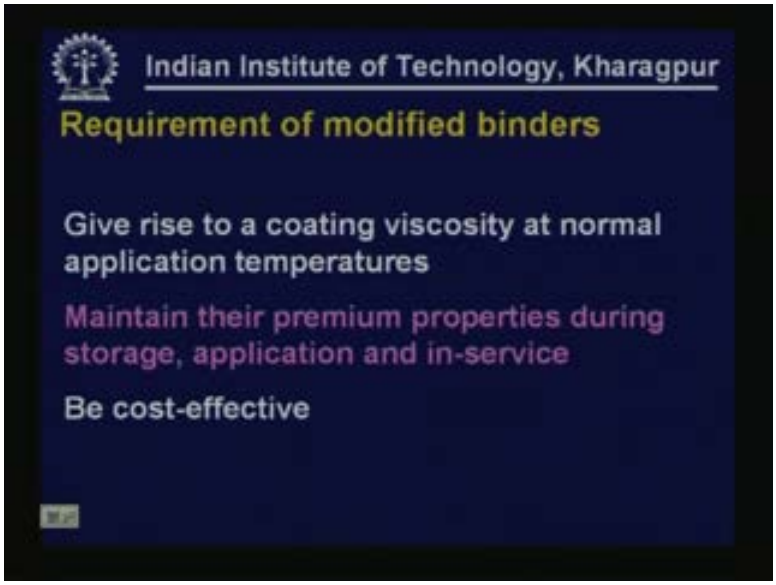

The use of modified binders generally gives rise to a coating viscosity at normal application temperatures. That means they should have viscosity ranges at normal application temperatures. So we should be able to use them at normal application temperatures and not that we should be using much higher temperatures for using these modified binders. And these modified binders should maintain their premium properties during storage, application and in service, the properties should not be changing significantly, obviously they should also be cost effective.

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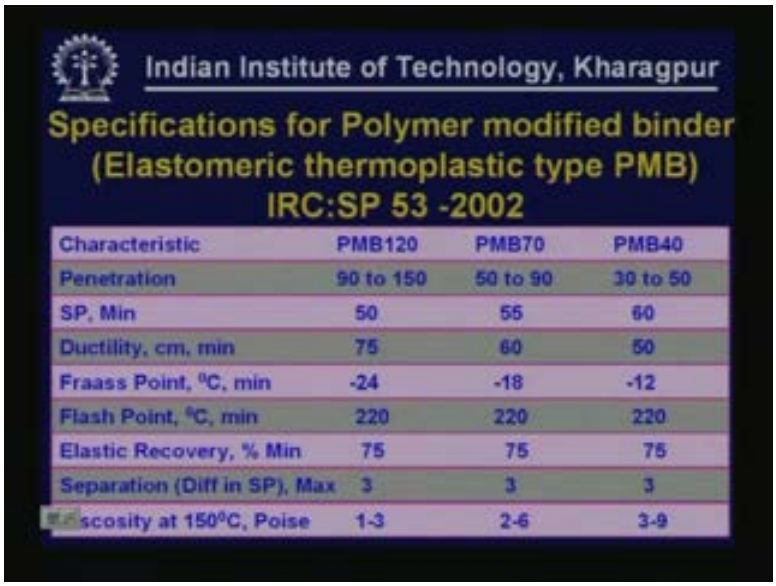

Typical specifications for Polymer modified binder: It is given as per IRC SP 53 - 2002 and SP indicates Special Publication. IRC has a special publication, specifications for polymer modified binders, elastomeric thermoplastic type, Polymer Modified Binder that is PMB. There are normally three grades of PMBs for use; PMB 120, PMB 70 and PMB 40 so the penetration range would be for PMB 120, 90 to 150. The softening point for PMB 120 will be a minimum of 50 degree centigrade, ductility should be a minimum of 75 cm for PMB 120, 50cm for PMB 40, obviously PMB 40y is much harder grade compared to PMB 120, flash point is 220 for all binders, Fraass breaking point is – 24 for PMB 120 and – 12 for PMB 40.

Elastic recovery is another property that we normally do not conduct for normal binders but this is the test that we conduct on modified binders. We will discuss about this after a few slides. So the minimum value specified for this is about 75 and there is a separation test that is also conducted to find out how stable the mix is, whether there is any separation of modified from the bitumen. Therefore there are two different parts of bitumen that is collected, softening points are tested, the difference should not be more than 3 degrees. Subsequently we will also briefly discuss how to conduct separation test. The viscosity of this modified binder conducted at 150 degree centigrade should be in the range of 1 to 3 Poise for PMB 120 binder and three to nine for PMB 40 binder.

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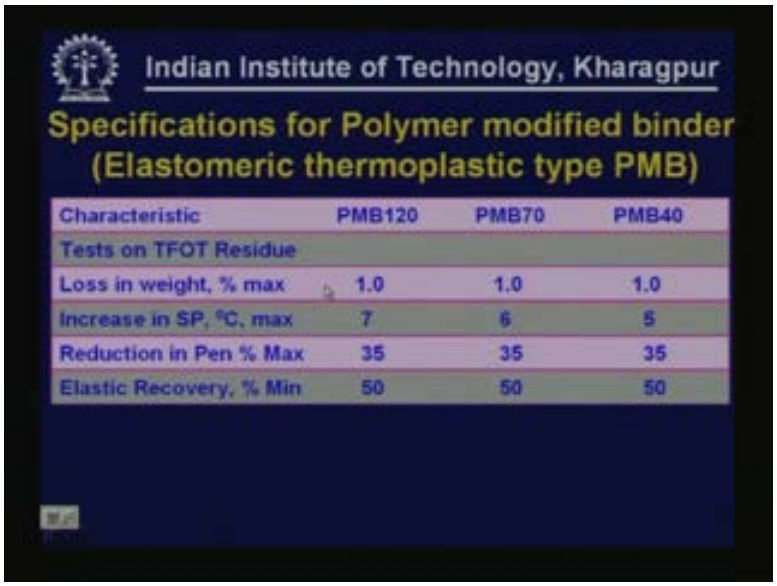

Further characteristic that are normally determined for these modified binders are by conducting TFOT test, and thin film oven test. So after the binders are subjected to TFOT we determine the loss in weight they should not be more than 1%, we determine the increase in softening point compared to the original binder and the aged binder, the increase in softening point should not be more than seven for PMB 120, more than 5 for PMB 40, the reduction penetration should not be more than 35, the elastic recovery of the thin film oven aged bitumen should be a minimum of 50. Similarly, we have specifications for other types of Polymer modified binders which are known as blastomeric thermoplastic. These (Refer Slide Time: 40:19) are further specifications for blastomeric thermoplastic type polymer modified binder.

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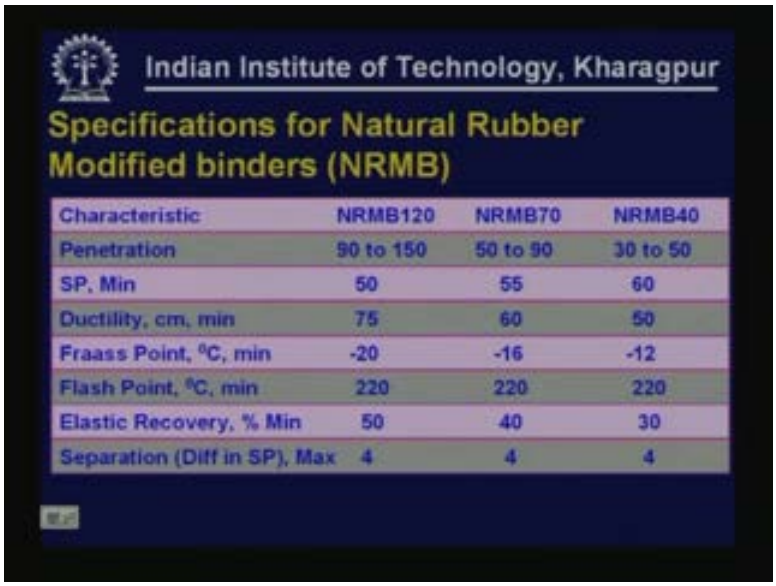

These are the specifications for natural rubber modified binders that is NRMB. We can see here that NRMB is also specified in terms of 120, 70 and 40 grade. The corresponding penetration values are similar to what is given in the case of PMB where the softening point minimum is 50, 55, 60.

Fraass breaking point – 20, – 16, – 12; ductility 75, 65; elastic recovery 50, 40, 30 where requiring much lesser elastic recovery. In this case the separation difference is a maximum of 4 for all these binders.

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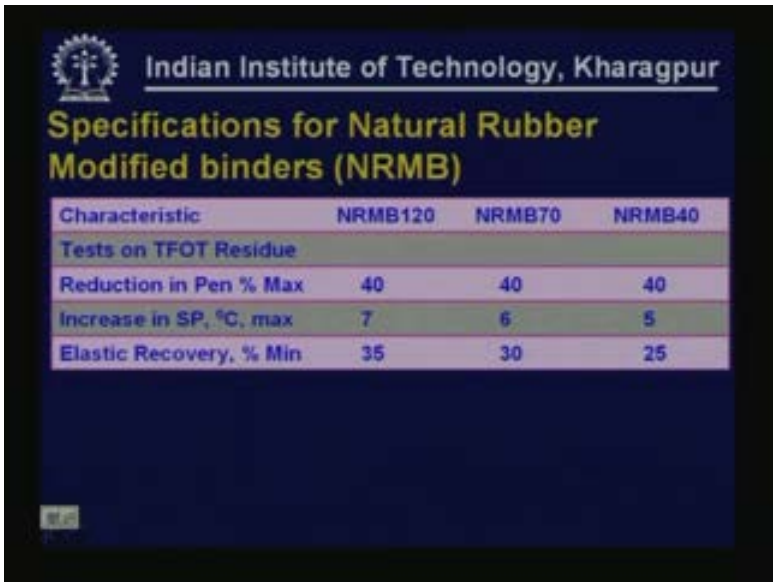

These are the TFOT requirements on the TFOT residue. Reduction and penetration should be maximum of 40%, increase in softening point should be a maximum of 7, 6, 5; elastic recovery on the residue obtained after TFOT test should be 35 thirty twenty-five for these three binders.

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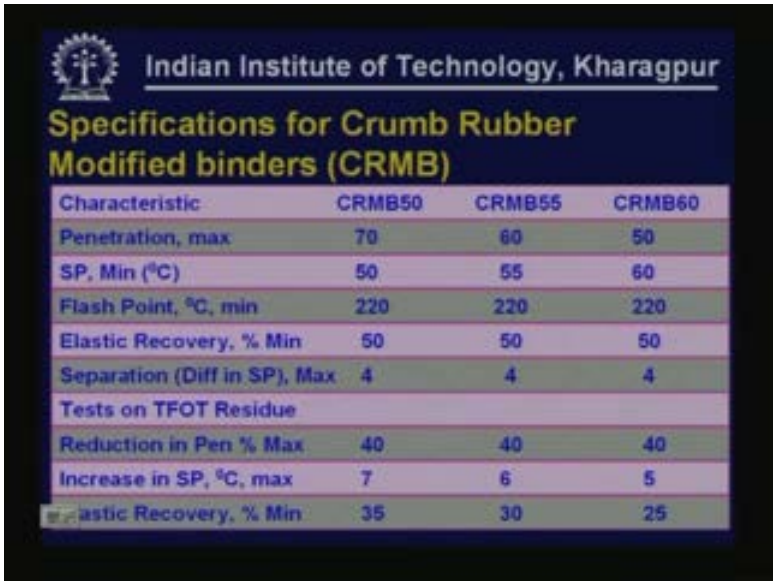

Similarly, we have specifications for Crumb Rubber Modified Binders. As I just discussed previously these are the binders obtained by blending crumb rubber which is obtained from old used tires from which those steel fibers or other fibers can be removed and it can be shred and then made into fine powder form or even smaller particles which can be added to bitumen and

then under appropriate conditions it can be blended. So those binders it has got different grades CRMB 50, 55 and 60. The specifications are 70 penetration, 60 penetration, 50 penetration but the specifications 50, 55, 60 as you can see is in terms of softening point. The softening point should be a minimum of 50, minimum of 55, minimum of 60 for CRMB 60. Similarly, other specifications are available in special publication of IRC 53.

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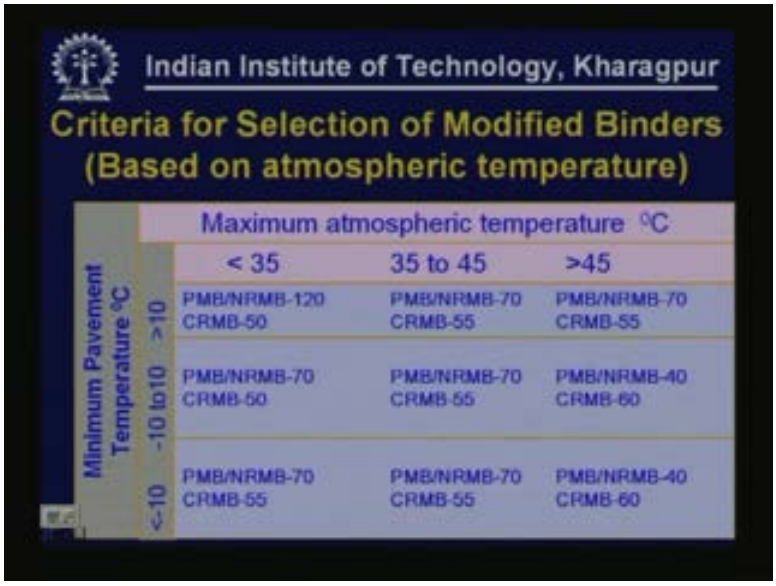

Let us examine the criteria that we have to adopt for selecting appropriate modified binders for different conditions. Usually these are based on atmospheric temperature. On the left hand side we have minimum pavement temperature ranging from – 10 to + 10 more than 10 and on the upper row we have maximum atmospheric temperature less than 35, 35 to 45 more than 45 and various combinations of modified binders that can be used are listed here.

For example, we have a location were maximum atmospheric temperature is more than 45 and the minimum of atmospheric temperature is more than 10 then we can examine PMB 70, NRMB 70 or CRMB 55. Whereas, if you have maximum temperature of 45 and minimum temperature less than – 10 degree centigrade the binders that are considered to be suitable are PMB or NRMB 40 these are harder grades and CRMB 60 this is the harder variety of CRMB binder.

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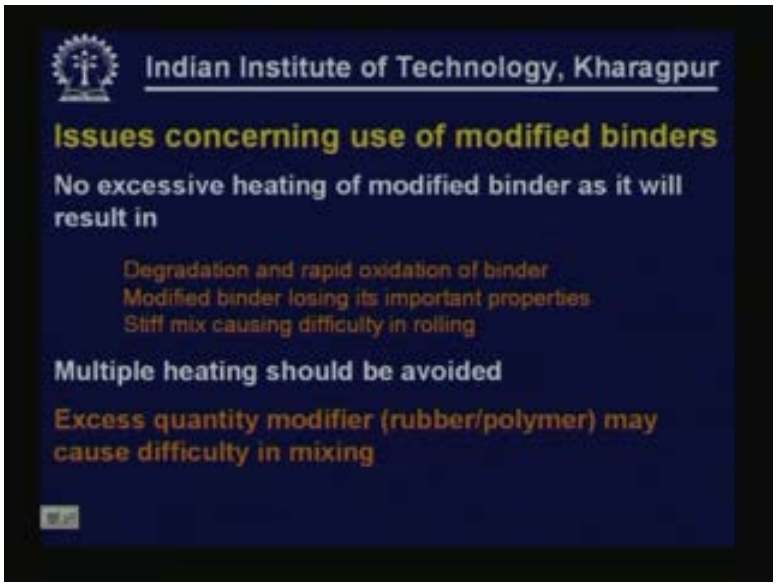

There are certain issues that we need to be concerned about when we use modified binders. These binders should not be heated excessively as it may result in degradation and rapid oxidation of the binder and the modified binder may also lose its important properties. Stiff mix may be formed causing difficulty in rolling so excessive heating should be avoided as far as possible. Also, we should not be heating this binder repeatedly, multiple heating should be avoided. Also, if you try to use excessive quantity of modified either crumb rubber or natural rubber or polymer this may cause difficulty in mixing. So, normally there is an upper limit on modified that can be added to binder that is also normally specified as either rubber or polymer.

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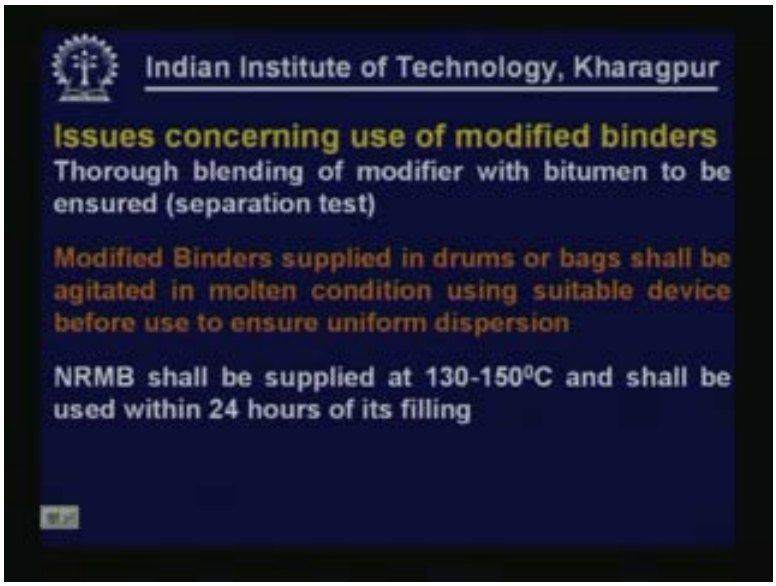

It is also necessary that thorough blending of modifier with bitumen is to be ensured. This can be ensured by conducting a separation test because the crumb rubber should not be floating in bitumen, polymer should not be seen separately so as far as possible the best possible blending should be obtained. Modified binders supplied in drums or bags shall be agitated in molten condition. These are usually specifications given by the manufacturer before the material is used. They will tell you that what are the conditions to be followed, to what temperature it has to be heated, how it has to be remixed again if it is required then that is how the binder has to be used. We have to look for the manufacturer specifications. Especially if NRMB which is supplied at 130 to 130, 150 degree centigrade, normally it has to be supplied at the temperature, should be used within twenty-four hours of its filling.

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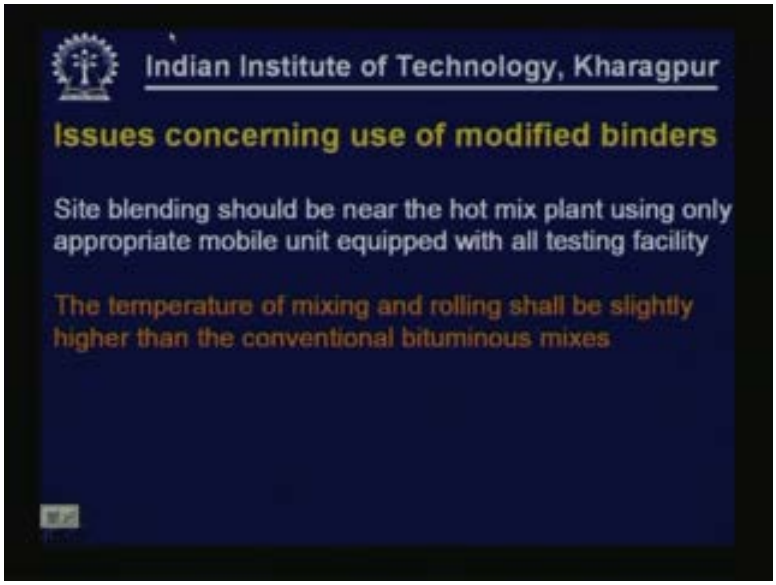

Site blending: in many cases the blending of rubber with bitumen, blending of polymer with bitumen is permitted but this should be done close to the hot mix plant by only using appropriate mobile unit. The temperature of mixing and rolling shall be slightly higher compared to conventional bitumens. When we are using modified bitumens all the temperatures normally related to mixing, rolling and other things will be slightly higher compared to the temperature that we maintain for normal mixes.

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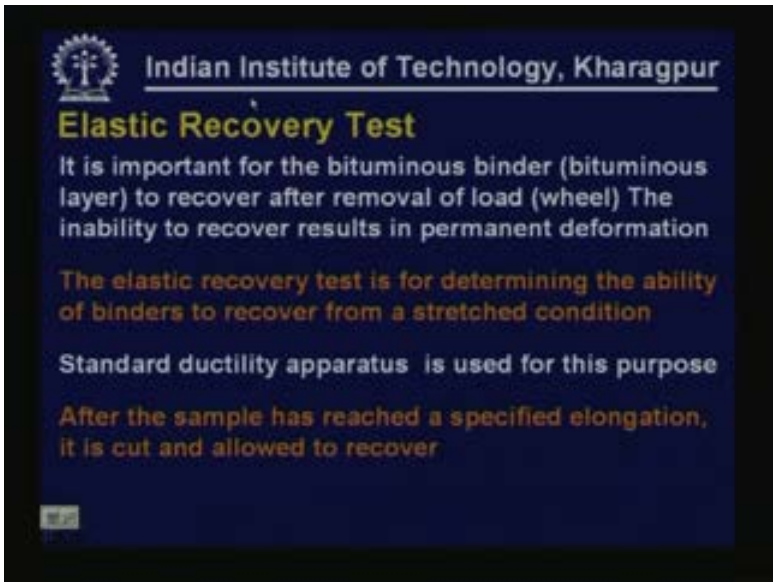

We talked about two different tests; one is elastic recovery test we specifically conduct for modified bitumens and also separation test. We will first start with elastic recovery test. This is very important for bituminous binder to recover after removal of load, that is the load that is caused by application of wheel load, the inability to recover results in permanent deformation. If it cannot recover then it leads to permanent deformation leading to rutting. So we want the binders to have sufficient ability to recover once the load is removed that is reflected in terms of elastic recovery. The elastic recovery test is for determining the ability of binders to recover from a stretched condition. What we do is we use standard ductility apparatus to conduct this test. After the sample has reached a specified elongation it is cut and allowed to recover.

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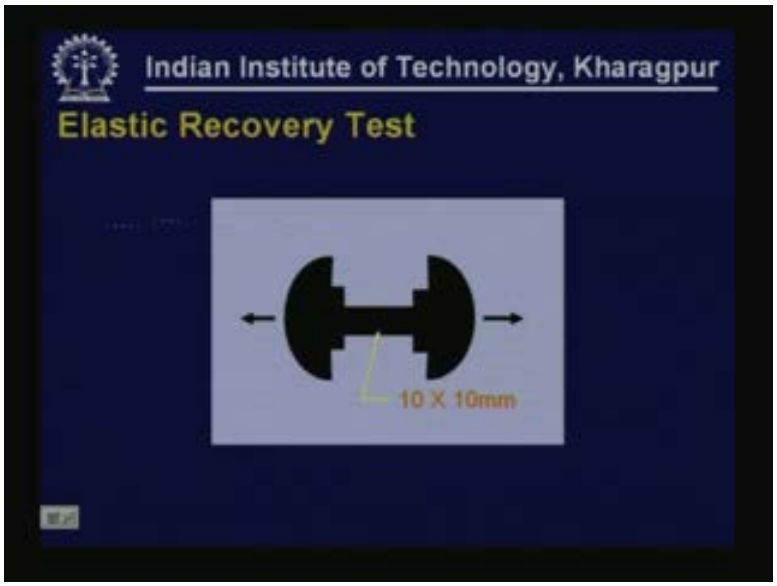

Slightly modified bricket is used. In this case ten by ten millimeters same size is there but it's not at one location but it is over some distance. So this bricket is stretched at same rate of stretching as we do in the case ductility five centimeters per minute.

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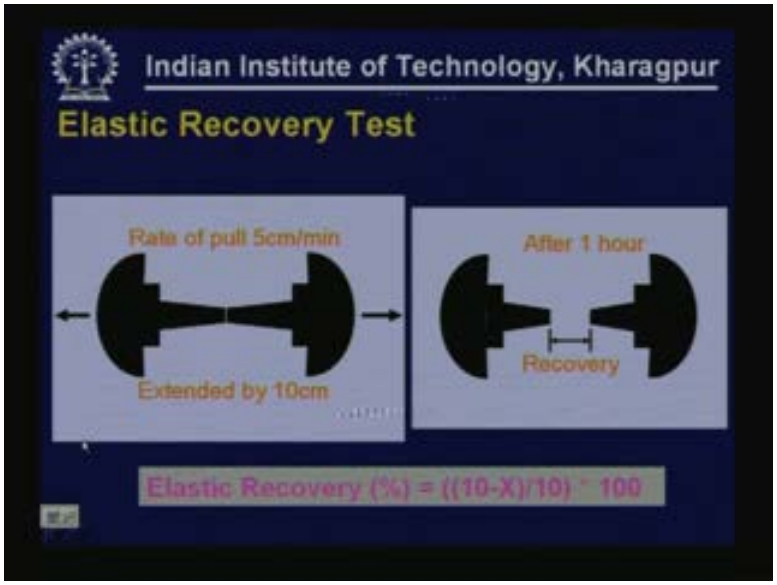

This is extended by 10cm at a rate of 5cm per minute and cut. After one hour we examine that there is some amount of recovery. So these two parts of brickets are bought brought together, its dimension is measured known as x, so elastic recovery is calculated as 10 that's the total

extension – x divided by x divided by 10 expressed as percentage that is obtained by multiplying by 100.

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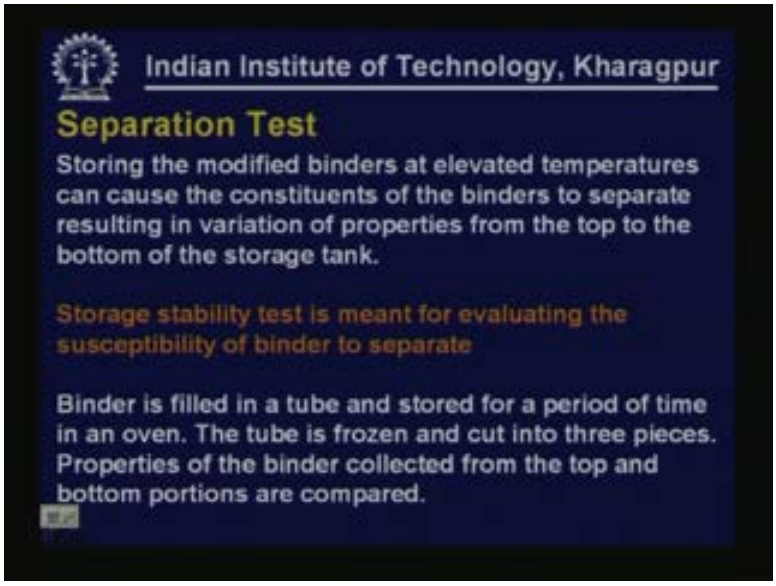

The separation test is done by storing the modified binders at elevated temperature. So storing modified binders at elevated temperatures can cause the constituents of the binder especially those modifiers that we have added to the binder to separate resulting in variation of properties from top to the bottom of the storage tank. So, on storage there could be some separation especially if the binder is stored at elevated temperature so if you collect a sample from top and collect a sample from bottom and determine its properties they can be significantly different if it is a binder which is proven to significant separation. Storage stability test is meant for evaluating the susceptibility of binders to separate.

What is done is the binder is filled in a tube and stored in for a specified period of time in an oven at a specified temperature. The tube is frozen so that it can be cut into three equal pieces. The properties of the binder collected from the top part of the tube and bottom part of the tube are compared.

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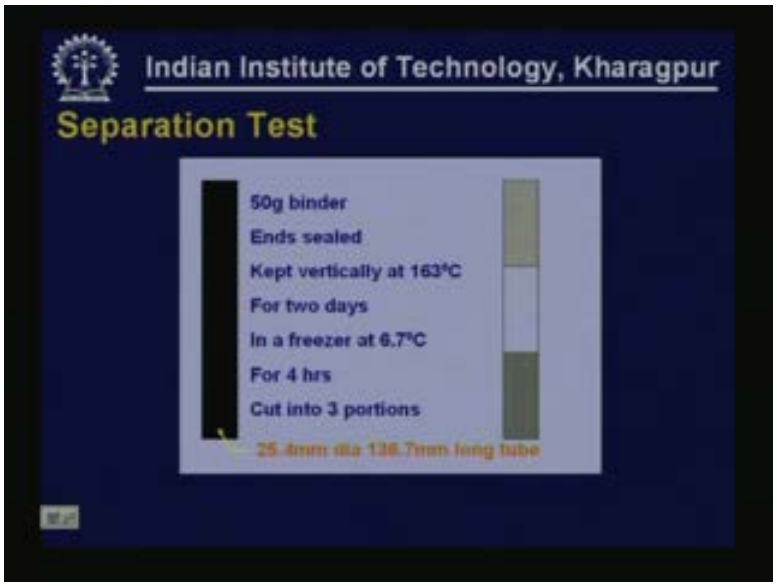

On the left hand side let's consider that to be a vertical tube which is filled with bitumen. About 50g of binder is used, the ends of this tube will be sealed, it is kept vertically at 163 degree centigrade in an oven it is kept like that for two days and after that it is taken out and kept in a freezer at 6.7 degree centigrade for four hours then this bitumen becomes quiet hard and now the tube can be cut into three parts without the bitumen coming out.

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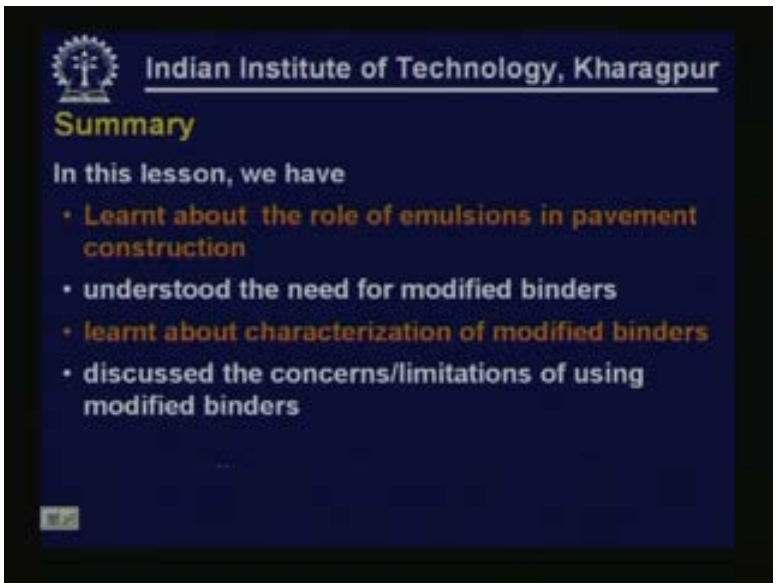

The size of the tube that has to be used is also indicated here. So, after it is cut you see those three parts. So the material that is taken from the upper part and the lower part will have to be

extracted and it has to be tested. As we have seen in the specifications especially it is the softening point that is used as an indication of what is the difference between the softening point obtained for the upper part bitumen and the lower part bitumen and that comparison in several cases the difference should not be more than 7 degrees and in other cases the difference should not be more than 4, 5 so different values are specified for different types of binders.

To summarize; in this lesson we have so far learnt about the role of emulsions in pavement construction. We have also tried to understand the need for using modifier binders in pavement construction especially when there are special situations like heavy loading, high temperatures, even very low temperatures, large temperature variations, standing loads and other special conditions. These are conditions were normal binders have been found to be not normally been very effective so then we may have to go for modified binders. We have also learnt about how to characterize modified binders, how the characterization of modified binders is different from that of normal binder. We have discussed the issues or concerns pertaining to the use of modified binders.

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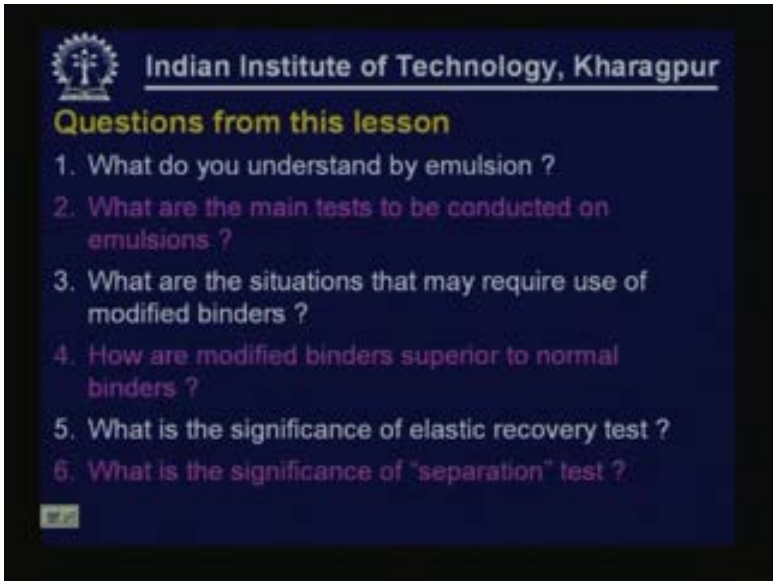

Let us take a few questions from this lesson. Answers to this will be provided in the next lesson.

1) What do you understand by emulsion?
2) What are the main tests to be conducted on emulsions?
3) What are the situations that may require use of modified binders?
4) How are modified binders superior to normal binders?
5) What is the significance of elastic recovery test?
6) What is the significance of separation test?

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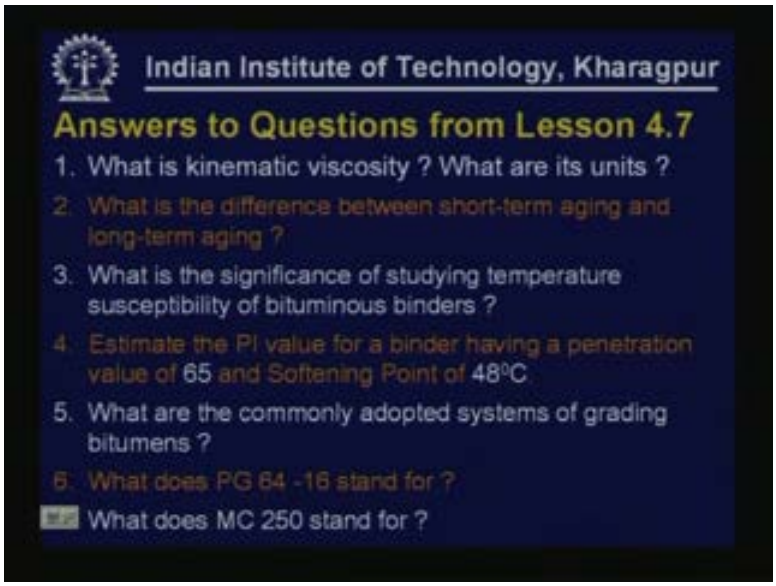

Now let us take up the answers for the questions that we asked in lesson 4.7. The first question was;

What is kinematic viscosity and what are its units?
We have seen that absolute viscosity is the fundamental property rheological property of bitumen but it doesn't really take into account the inertial force. So it has been seen to be convenient to use the ratio of viscous force and the inertial force, so that is what kinematic viscosity is about. Its absolute viscosity divided by the density of the fluid. Its units are usually in terms of meter square per second, in Cgs (00:53:15) units it's also expressed in terms of stokes but more commonly it is expressed in terms of centi stokes.

2) What is the difference between short-term aging and long-term aging?
In the case of bitumens they are subjected to various operations, various processes while it is used, while it is mixed with aggregates and also while it is in service. So these binders undergo aging. The aging that occurs over a short-term period during initial mixing, storage, transportation and laying process so the aging that is occurring during that process is called a short-term aging. On the other hand during the service life period the aging that occurs because of various parameters during service life period this could be over five ten fifteen years period is long-term aging.

3) What is the significance of studying temperature susceptibility of bituminous binders? you need to understand this temperature susceptibility of bituminous binders because we want binders that would perform satisfactorily at high temperatures, that would also perform satisfactorily at very low temperatures. The binder should not normally be very soft at high temperature otherwise we will have a problem of rutting, permanent deformation and so on, it should not be very stiff also at very low temperature otherwise these will crack at low temperatures. This is the phenomenon we are interested in. This is normally obtained by

conducting either penetration test or viscosity test at different temperatures examining those plots.

Next question is estimate the penetration index value for a binder having a penetration value of 65 and a softening point value of 48 degrees. We already have the expression given in the previous class, penetration index is equal to 1952 – 500 log penetration which is 65 here – 20 times the softening point values which is 48 here divided by 50 times log of penetration, penetration value is 65 here minus softening point that is 48 here – 120 so this expression can be used to work out the penetration index value.

What are the commonly adopted systems of grading bitumen?
Bitumens are normally graded in terms of penetration in terms of viscosity and also there is another system known as superpave gradation system in which maximum service temperature and minimum service temperature are taken into consideration.

6) What does PG 64 – 16 stand for? PG 64 – 16 refers to a binder that would perform satisfactorily for a maximum service temperature of 64 and for a minimum service temperature of sixteen so within that range this binder is going to be satisfactory.

What does MC 250 stands for?
MC is a medium curing cutback and 250 stands for viscosity of this cutback in centistokes at 60 degree centigrade temperature, thank you.