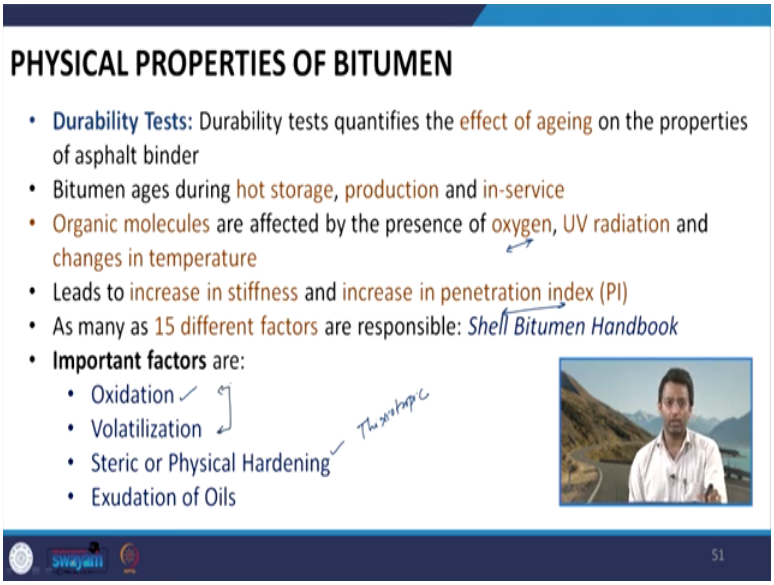
**Pavement Materials**
**Professor. Nikhil Saboo**
**Department of Civil Engineering**
**Indian Institute of Technology, Roorkee**
**Lecture No. 25**
**Physical Properties of Bitumen (Part-3)**

Welcome back friends, if you remember, in the last class we are discussing about the Physical Properties of Bitumen. In the last class, we covered different consistency tests, which are used to characterize the flow behavior of bitumen. This lecture is a continuation of the last lecture.

(Refer Slide Time: 00:48)




Today, we will start by discussing about the durability aspects of bitumen. When we talk about the durability test, what does durability signify? Durability indicates the ability of any material to retain its desirable properties over its lifetime. When it comes to bitumen, we are more interested to see how aging effects the properties of bitumen over a period bitumen ages during different stages of its use it ages when it is during its hot storage, it ages during the production when it is mixed at elevated temperature with the aggregates.

And after the compaction in the field, when the pavement is open to service it ages during its service period also, what happens during aging that the organic molecules of bitumen which are present in the bitumen, they get affected by oxygen by UV radiation and also by changes in temperature. Here oxidation is reaction with oxygen is the most important factor which contributes to the ageing of the bitumen.

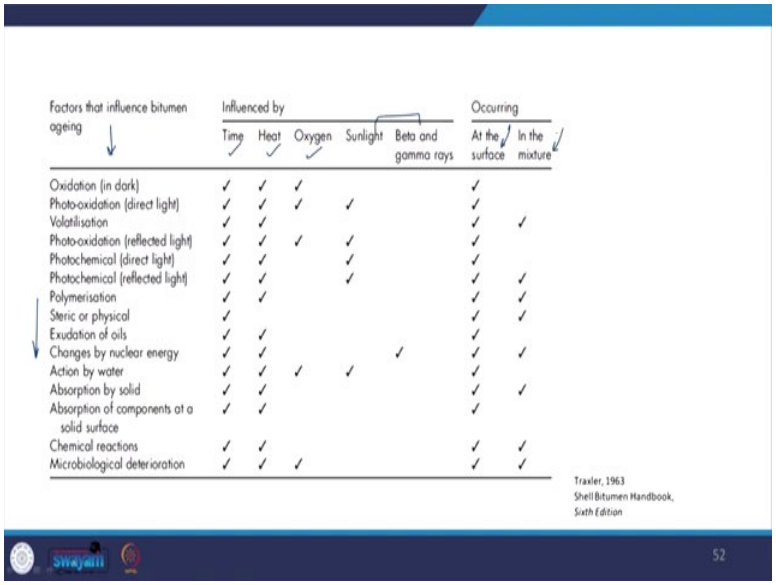
Because of these processes, it can be an oxidation, it can be the effect of UV radiation, it can be the effect of changes in temperature. Finally, the stiffness of the bitumen increases as a way of describing stiffness let us say we talk about the penetration value and the softening point value. So, what we expect that after aging the penetration of the bitumen will get reduced and the viscosity and the softening point of the bitumen will be increased.

Of course, the extent of this change that is reduction in penetration or increase in viscosity and softening point will depend on various other factors including the type of bitumen we are dealing with; the aging of bitumen, it also increases the penetration index and if you remember penetration index is basically a parameter which indicates the temperature and susceptibility of bitumen, which we have discussed in our previous classes.

Shell Bitumen Handbook has given almost 15 different factors that are responsible for ageing of bitumen among these different factors, the important factors which are identified are as follows oxidation which I said is the most important factor contributing to the aging of bitumen volatilization were the lighter components in the bitumen and if you remember from our discussion on chemistry of bitumen, for example, the multi infections they get evaporated because of high temperature.

Another important factor is the steric or physical hardening of the bitumen; we will be discussing about what actually is a steric or physical hardening. This is also sometimes called a thixotropic hardening of bitumen. And the fourth important factor which contribute to aging is the exudation of oil. Before even we move forward, I wish to comment here that even out of these four factors, the first two factors are found to be more critical.

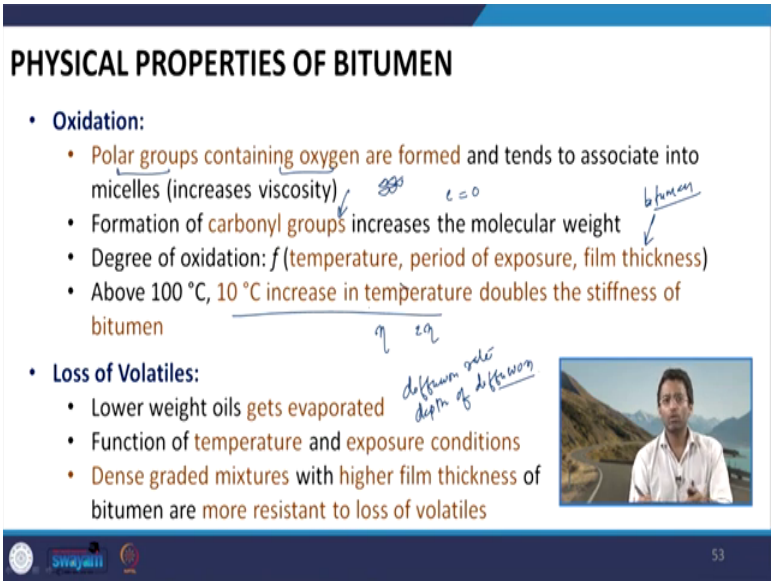
(Refer Slide Time: 04:17)



These are the 15 different factors which Shell Bitumen Handbook has shown that affects the aging of bitumen. You can see in the first column, we have factors that affect bitumen aging you can see the list we have oxidation, photo oxidation volatilization we have polymerization steric or physical hardening and so on.

There are so many different factors, and these factors are in turn influenced by various other parameters such as the exposure time, the temperature at which the bitumen is exposed or heated oxidation, UV radiations and also the position of the mix in the pavement, whether the aging is happening at the surface or the aging is happening within the mixture.

(Refer Slide Time: 05:14)




Let us now discuss about these important parameters which we say contributes to aging one by one, let us start with oxidation, what happens in oxidation is that the exposure of bitumen to oxygen create polar groups that contain oxygen, and it tends to associate into micelles which means, it will agglomerate into larger size and this tends to increase the viscosity of the bitumen.

Specifically, we will see that because of oxidation there will be a formation of carbonyl group and a carbonyl group is nothing but a functional group having a carbon atom double bonded to oxygen. So, we can have several different molecules in this form. So, it leads to the formation of carbon and groups for example, we have ketones we have carboxylic acids and so on.

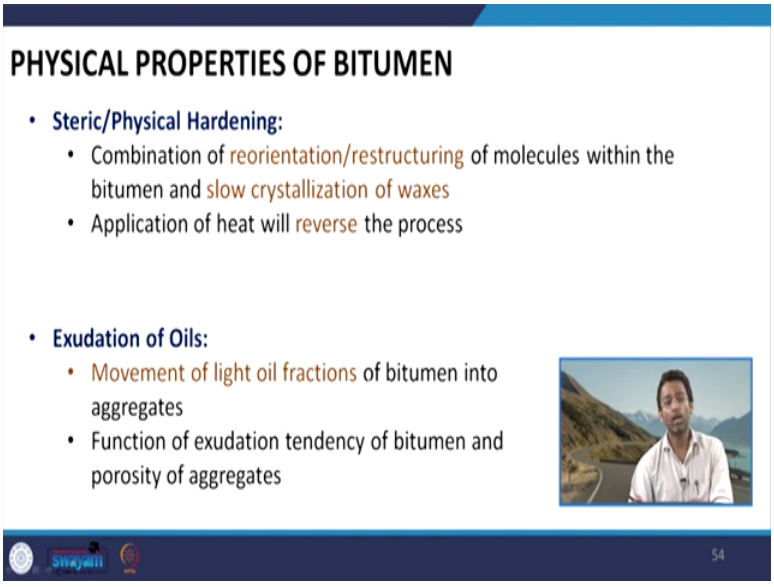
So, this carbonyl groups they increase the molecular weight because of this oxygen atom being attached to the molecular system, the degree of oxidation, it depends on various factors. For example, the temperature at which the bitumen is exposed to it also depends on the period of exposure, how long the bitumen is exposed to oxygen. It also depends on the film thickness, which is basically the bitumen film thickness over the aggregate particles.

If we talk about the effect of temperature, studies have shown that above 100 degrees Celsius 10 degrees' Celsius increase in the temperature of bitumen can double the stiffness of the bitumen This means that if we have a bitumen let us say we are hitting it at 160 degrees Celsius and at 160 Celsius the bitumen viscosity Now, let us say is Nita and if we hit the bitumen at 170 degrees Celsius, which means we are increasing the mixing temperature by 10 degrees Celsius. So, the bitumen which we will get after heating it to 170 degrees Celsius will have an approximate viscosity of 2η.

So, this means that the extent of aging is very high, especially at higher temperatures. The other factor which contribute to aging is volatilization or the loss of volatiles, here the lower weight oils, they get evaporated when the bitumen is subjected to higher temperature and what are these lower weight components, they are basically the components from the multi infection of the bitumen loss of volatile is definitely a function of temperature and also exposure conditions.

Loss of volatiles basically depends on the diffusion rate and also the depth of diffusion. Therefore, if we have a dense graded mix with higher film thickness, which lowers the depth of diffusion, in that case, the loss of volatiles will be relatively low. Another important point to note here is that most of the paving grade bitumen, which is produced in the industry, they basically have lower volatile components and therefore, this factor is not very, very significant.

(Refer Slide Time: 08:32)



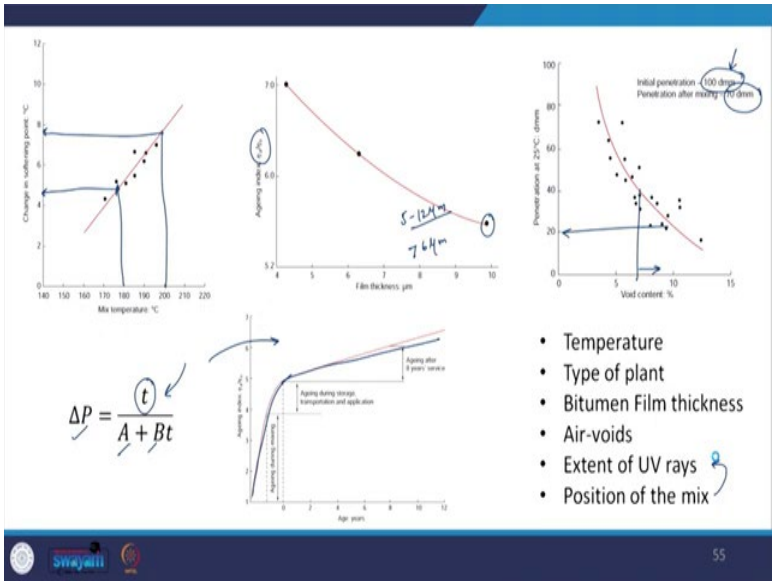
The next factor which we are going to discuss is the steric or physical hardening. What happens here is that even if you keep the bitumen at a room temperature for a certain period, it may happen that the viscosity of the bitumen increases, you are not hitting it, you are just keeping the bitumen at a particular place. Why is this happening because bitumen has some polar components.

If you remember for example, asphaltene is a polar molecule or group we have reasons which are also polar molecular group. So, these molecules are groups now, since they are polar, they have hetero atoms attached to it, they have the tendency to interact also within each other. So, they interact with each other, the molecular orientation can get changed, it can reorient itself it can restructure itself.

And therefore, finally, the viscosity of the bitumen can increase steric hardening can also happen because of slow crystallization of waxes which are present within the bitumen system. However, this process is reversible. If you apply the heat the association which has been formed will disassociate and the bitumen will go back to its initial state. So, this is basically a reversible process where is the first two factors which we have discussed, that is oxidation and volatilization. They are irreversible processes.

The last factor in our list is exudation of oils here what happens the lighter components or the oil fractions within the bitumen, they may sometime seep inside the aggregate ports. Now, this depends on the exudation tendency of the bitumen, that how readily it allows the oil fraction to come out of it and it also depends on the porosity of the aggregates. Of course, if the porosity of the aggregate is higher, the chances of oil oxidation become higher out of these are all factors which we have discussed, I just want to reiterate that oxidation of bitumen is the most critical and important factor which contributes to the aging of bitumen.

(Refer Slide Time: 10:49)



Now, let us see that, how different factors affect the aging phenomena, and it changes various properties of the bitumen or the bituminous mixture. The first graph which you see here is the graph between the change in the softening point in the y axis and the mix temperature. So, these graphs tell us that how the temperature at which we are exposing the bitumen, it can change the aging phenomena.

If you see that around let us, say 180 degrees Celsius, the changing softening point of the bitumen is somewhere around 4 to 6 degrees Celsius. The same bitumen is subject to a temperature of let us say 200 degrees Celsius, this change can be as high as more than 7.5 degrees Celsius. This shows that how critical is the effect of temperature on the ageing process of bitumen, sometimes what happened that let us say we have made a bituminous mixture and it has been taken to the site or it is still in the plant and there is some delay in the process of compaction in the field.

So, sometimes practitioners or contractors they have a tendency to heat the bituminous mixture just to ensure that the workability is proper, because the logic here is if you increase the temperature of the mixture, the viscosity of the bitumen will come down and that will facilitate the workability of the mixture. However, we have to realize that this increase in temperature if you are heating, additionally the mixture the bitumen is getting exposed to higher temperature which can parallelly lead to subsequent aging within the mixture and this can be very detrimental to the long term performance of the final bituminous mixture.

The second graph it shows the effect of franticness the bitumen same thickness over the aggregate particles on the ageing index and what is aging index here it is a representation of the extent of ageing. So, here ageing index is defined as the ratio of the viscosity of the binder after ageing and the viscosity of the binder before ageing. So, you can see that higher is the film thickness of the bitumen over the aggregate particles lower is the ageing index, which means that a bituminous mixture with sufficient film thickness can reduce the ageing of the mixture.

Typically, the film thickness somewhere ranges from around 5 to more than 12 micrometers. So, some of the literature says that on an average the desirable bituminous film thickness is greater than 6 micrometers. The third graph it shows the variation of penetration at 25 degrees Celsius versus the void content in the bituminous mixture. So, this graph tells us how the voids in the bituminous mixture affect the aging phenomena.

Here you see that the initial penetration of the bitumen which was taken from the refinery was found to be 100 decimeters and the penetration of the bitumen which was obtained after mixing it with the aggregates was found to be 70 decimeters. So, of course, the bitumen has undergone some aging during the mixing process, because of which the penetration has reduced.

Now, what they have done, they have extracted this bitumen from different mixtures which have variable void contents. And what they found that when the void content in the mixture is typically let us say more than around 6% There is a very significant reduction in penetration of the extracted bitumen from the mixture So, lower are the air voids within the bituminous mixture lower will be the extent of aging people have also tried to see that how bitumen ages over a period. And few of these studies have agreed that a hyperbolic model can be used to describe the change in the material property with change in time.

Here ΔP is the change in any property, let us say it can be a penetration, it can be softening point it can be the viscosity, t is the time at which we are measuring the change in the properties and A and B are model parameters. So, here this can be seen from this particular graph, where you see that in the initial period, when the value of t is less for example, let us say when we have taken the bitumen, use the bitumen for the production in the mixing plant and we have compacted it in the field you will see that there is a steep increase in the viscosity of the bitumen, where the y axis represents the aging index which means the viscosity has increased at a very faster rate.

Once we have completed the bitumen in the field, now, the mixture is not exposed to the extent of temperature it was exposed in the mixing plant, we were exposing the mixture to a temperature let us say around 160 to 170 degrees Celsius, maybe more than 150 degrees Celsius, when we compacted in the field, the temperature of the mixture was still higher, higher than 100 degrees Celsius may be in the range of 100 to 130 degrees Celsius.

Now, once the mix has been finally compacted, the temperature has come down and the pavement is open to traffic. Now, the temperature of the bitumen or the mixture, it depends on the ambient temperature or the temperature of the location where we have used the mix. But of course, that temperature will be typically less than let us say 70 degrees Celsius.

So, after the bitumen is put into service after the bituminous mixture is put into service, the exposure to temperature get reduced. And now the rate of aging, it slows down and you can see that gradually the slope reduces and this slope here it of course depends on various factors of the mix of the bitumen of the film thickness of the bitumen over the aggregates and so on.

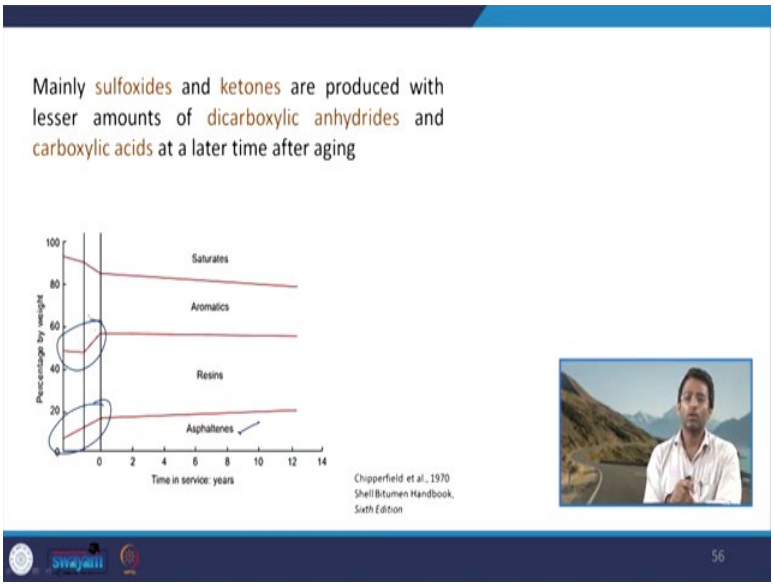
So, overall, what we have discussed up to this particular slide is that aging is a phenomenon that increases the viscosity of the bitumen, which changes the properties of the bitumen over a period of time and there are various factors which can affect the aging process temperature is one of the factor.

In fact the type of plant can also affect the extent of aging, the same mix when produced in a drum mix plant will have a lower aging in comparison to the mix if it is produced in a batch mix plant why because in the drum mix plant, there is a presence of water vapor which reduces the oxidation process the aging

also depends on the bitumen film thickness, higher different thickness more is the resistance to aging, it depends on air voids, lower the air voids more the resistance to ageing, it also is dependent on the extent of UV rays.

Now, this is typically applicable to the only top few inches of the mix where the sun rays are basically incident. So, because of the UV rays, which are falling few inches first few inches of the bituminous mixture can have higher ageing in comparison to the mix, which is at a lower depth. And it also as I said now, this this is something which I already mentioned that the extent of aging also depends on the position of the mix, since the top surface is exposed more to oxygen and UV radiations it is obvious that the extent of aging will be higher than the top surface maybe first few inches of the mix in comparison to what we get at the lower depth.

(Refer Slide Time: 19:24)



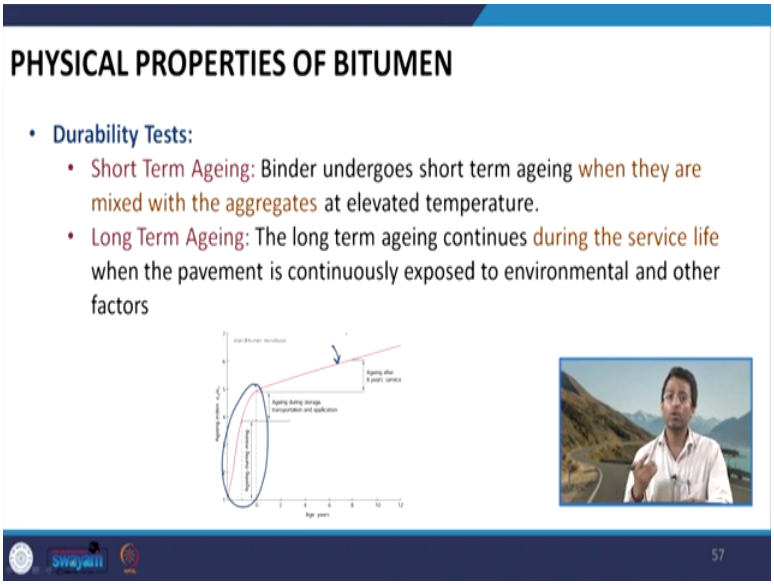

This slide shows how the chemical components in the bitumen changes because of aging. Very briefly we have discussed about the chemical components of the bitumen in the second lecture, if you remember, therefore, this slide we will be able to easily understand what happens is that because of oxidation when this oxygen atom gets attached to the molecule of the bitumen, mainly sulfur oxides and ketones are produced, which increases the molecular weight of the entire system.

Lesser amounts of dicarboxylic and hydrates can also be produced, and carboxylic acids are also produced typically at a later time after aging. Now, this is what happens in the molecular orientation. If you see the four components which we discussed that is Sara fraction saturates, aromatics raisins and asphaltenes, it is seen that because of oxidation, the lighter components the oily fractions the aromatic fractions, especially in the initial period during the production, there is a reduction in the amount of aromatic.

So, what happens when the lighter fractions are exposed to oxidation for example, aromatics they will get converted to resins like molecules resins like molecules will get converted to asphaltene like molecules. So, you see the asphaltene content it will increase over a period, but the extent of increase is more significant during the production and compaction process.

Similarly, the aromatic fractions and the resins fractions they tend to increase in the initial period, but once the bituminous mixture is put in service, the extent of the change will become lower, and which is obvious because the extent of oxidation will get reduced. And additionally, it is seen that the change in saturate is not very extensive in comparison to the change in aromatics and resins. Having said this, since now, I hope that we understand that what is ageing and what are the factors that contribute to ageing.

(Refer Slide Time: 21:54)




Now, let us see that how we can simulate aging in the laboratory and try to study the ageing phenomena of bitumen, the entire ageing phenomena can be broadly divided into two parts short term ageing and long term ageing, short term ageing of the bitumen happens mostly during production and mostly during compaction.

So, the binder, it undergoes aging when it is mixed with the aggregates at elevated temperature and is finally compacted in the field after compaction when the temperature of the bituminous mixture comes down and the pavement is open to traffic is slow process of ageing will start and this will continue up to the entire life of the bituminous mixture. And this phenomenon is called as long-term ageing.

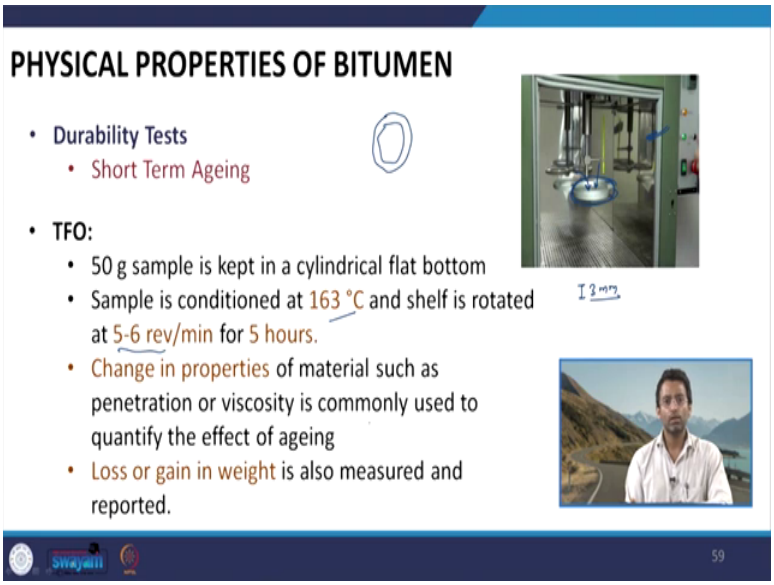
So, this graph we have already seen in the previous slide and just to recall the importance of this graph that the ageing is more significant during the mixing, production and the complexion of the bituminous

mixture. And during in service, the rate of change in ageing or increase in ageing is relatively slow. Here an important point to note is that short term ageing basically happens because of two process loss of volatiles and oxidation they act simultaneously during the production stage. Whereas in long term ageing, it is mostly the oxidation which is more critical.

(Refer Slide Time: 23:37)


Therefore, in the laboratory, whatever test we will use to simulate this process should consider these two effects. So, to consider the effect of oxidation and to consider the effect of volatilization short term ageing is done using a thin film oven or a rolling film oven, they are used to simulate the hardening process which happens during the production stage of the bituminous mixture. The first picture it shows a thin film oven whereas the second picture it shows a typical rolling thin film oven.

(Refer Slide Time: 24:13)



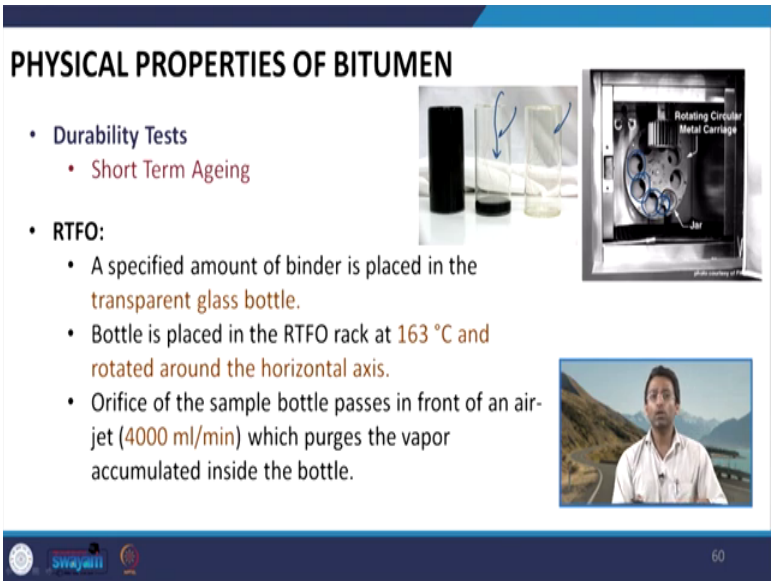

Let us discuss about these test methods one by one. Let us start with it thin film oven test. Thin film oven is a simple ageing test where we have an oven and we have a plate arrangement to keep the bitumen now, since in the plant, the bitumen is basically occupies a very thin film over the aggregate particles. Therefore, in the lab also the depth of bitumen is kept low to replicate this thin film which is present during the production process.

Here approximately 50 grams of bitumen is taken, and it is kept in the cylindrical flat bottom. When you put the 50-gram bitumen in this cylindrical flat bottom it will occupy approximately the depth of the film which will be created will be approximately 3 mm and this 3 mm of bitumen's film which we create is exposed to higher temperature which is similar to what we get during the production process.

So, the conditioning is done at 163 degrees Celsius which you see is a very high temperature and the shelf is basically continuously rotated at 5 to 6 revolutions per minute and this process is carried out for 5 hours, after the completion of the test, we will take out the bitumen from the oven.

And we can measure the change in properties of the bitumen, which is changing property after the ageing and the property which we measured before ageing and this property can be anything it can be a change in penetration, change in viscosity change in softening point any parameter can be used to quantify the extent of ageing that has taken place the loss or gaining weight can also be reported after the test.

(Refer Slide Time: 26:13)




Coming to the rolling thin film movement test. This test is a form of variation of the thin film movement test, it is expected to age the bitumen to the same degree that we get in the thin film movement test, but in a relatively lesser time. What we do here is that we have some transparent glass bottles which you can see.

So, a specific amount of bitumen is first taken, and it is put inside the glass bottle this glass bottle is manually rotated. So, that this bitumen covers the periphery inside circumference of the bottle, and it occupies a thin film there we have several bottles and these bottles can be kept horizontally in these slots inside the rolling thin film oven.

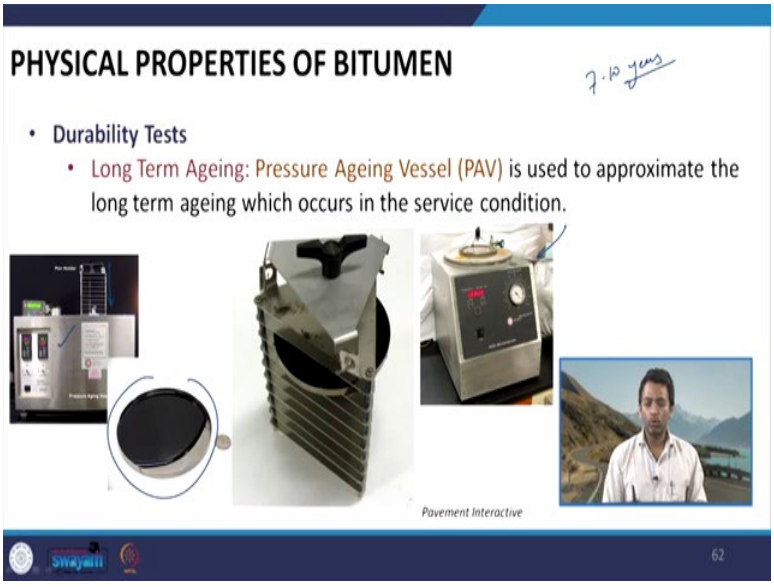
The bottle is placed inside the rack at 163 degrees Celsius and it is rotated around the horizontal axis. Further, what is done in this test is that the orifice of the sample bottle it will pass through a point where we will blow air jet and this air jet is blown around 4000 ml per minute, which helps to purge the vapor which gets accumulated inside the bottle. So, this rotation inside the rolling film thin oven is carried out for a period of around 75 minutes.

After which we will take out the bottle, we will scrap the material from inside the bottle we will collect the bitumen in in a container. And this bitumen we can further subject to testing similar to what we have done in the thin film movement test we can measure the change in physical properties, we can measure the change in rheological properties and then quantify the extent of short-term aging that has taken place in the bitumen.

(Refer Slide Time: 28:12)


These are some typical pictures of a rolling thin film oven and set just for your reference, you can see that we have a oven and this is what the inside of oven looks like a close up view, where you can see that these bottles are placed filled with bitumen and we have an air jet here which will blow air near the orifice of the sample bottle as it keeps rotating inside the rolling film oven.

(Refer Slide Time: 28:51)




Talking about the long-term ageing. Long term ageing in the laboratory is simulated using a pressure ageing vessel. And just to remind you, here we are trying to see the effect of oxidation because oxidation is the primary factor which influences the long-term ageing of the bitumen in the field also. So here a pressure-

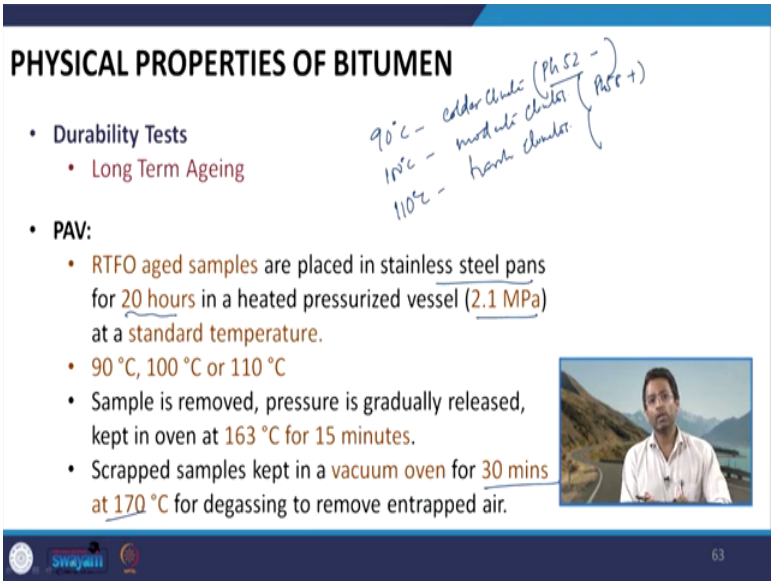
based process is used where we accelerate the ageing which is going to happen for a period of around seven to 10 years in just few hours in the laboratory.

When this method was developed, it was developed in the Iowa State University. Several trials were done to change the pressure the bitumen is exposed to the temperature the bitumen is exposed to and the duration for which the bitumen is exposed to that temperature. And then the results of the obtain aged binder were compared with the results of that which is obtained from the field.

And finally, several changes were made. And some standards were defined by which we can subject the bitumen to long term ageing such that this bitumen which we get after the aging process will be similar to the bitumen which we will get from the field after approximately 7 to 10 years of service.

These are some of the components of the pressure ageing vessel, we have a pressure ageing vessel here these are this is a tray system or a pan holder and this is the pan which is put inside this pan holder. So, several pans can be put, so, that the amount of bitumen, which can be aged at a particular time is higher and then we have a vacuum oven system to further do the conditioning.

(Refer Slide Time: 30:40)




If we talk about the procedure, here we take the RTFO aged sample because in the field also long-term ageing will happen only after the short term ageing. So, therefore, it is important that the bitumen which we take and subject to long term ageing is actually the bitumen which has already undergone the short-term ageing process. So, we take our RTFO aged binder, and it is placed in the steel pans which I just showed you in the previous slide.

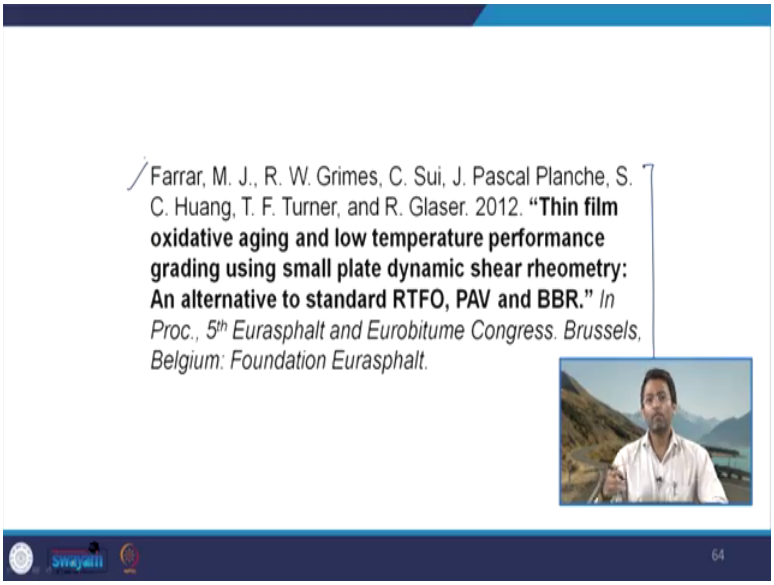
And it is kept inside the pressurizing vessel for 20 hours and the pressure which is applied is approximately 2.1 mega Pascal. Initially when the test was developed, only 100 degrees Celsius was used to subject the bitumen to long term ageing. But then, it was found that these 100 degrees Celsius can be too harsh for bitumen which is actually used in a relatively colder environment. And it can be too low especially for mixes which are used at a location with very high temperature very harsh climates.

Therefore, finally three temperature ranges were decided based on the location where we are going to use the bitumen 90 degrees Celsius is used in a relatively colder climate where typically we will use a bitumen of performance grade 52 or less. We will talk about the performance grade later in the presentation. This is a way of grading the bitumen as per the super pave grading criteria 100 degrees Celsius is used for moderate climates. Typically, where the bitumen which will be used will be PG 58 or higher.

And 110 degrees Celsius is used for harsh climates where the bitumen which typically will be used will be of very stiffer grades, after we subjected the samples to this pressure for this time of 20 hours and at a particular standard temperature. The sample is further removed from the pressure ageing vessel after releasing the pressure very gradually, and then the sample is kept in the oven at 163 degrees Celsius for 15 minutes.

After that, we will scrap the sample from the cans and we will put it in a vacuum oven for 30 minutes at 170 degrees Celsius and this is done to degass, the entrapped air if any, which might have come from the pressure ageing vessel. So, after the completion of this process, we have the final binder, which is a long-term age binder. And we can further subject this binder to various tests and can determine the extent of ageing, which has occurred in that sample.

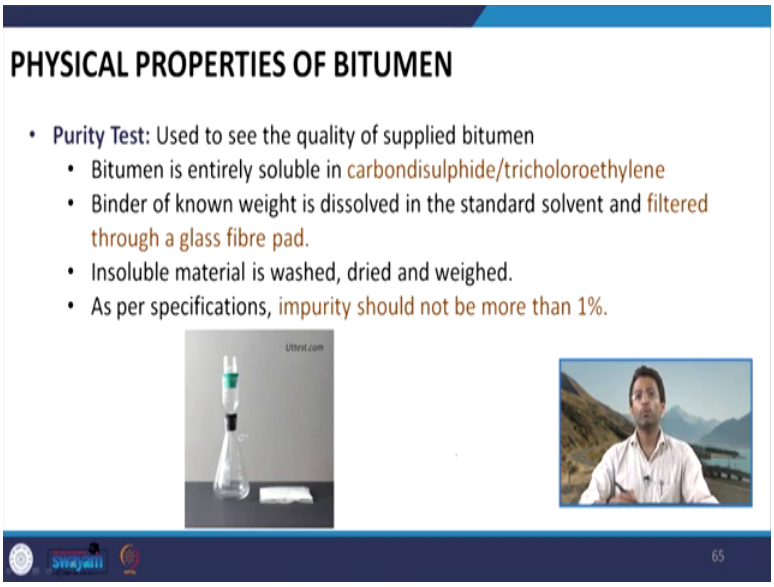
(Refer Slide Time: 33:50)



Now, researchers over a period of time they have debated upon these ageing methods on whether they really are able to simulate the short-term ageing or the long term ageing and researchers have also tried to find more simple methods which can be used in the laboratory using simple equipment's. And the final goal is to get a binder which represents, or which can simulate the actual short term ageing and the actual long term ageing.

So, this particular paper is one such paper that have tried to evaluate the use of a simple draft oven for simulating short term ageing and long-term ageing of asphalt binders like this, there are several other papers but this is one paper which have been referred to even by other researchers for ageing their binder using a simple draft over. So now, we have come to the end of our discussion on the ageing of bitumen and the tests which are used to quantify the ageing in the laboratory.

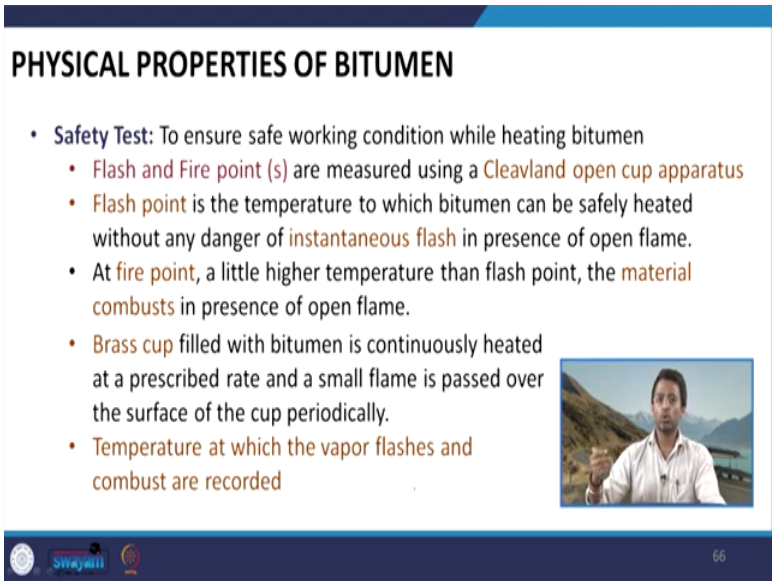
(Refer Slide Time: 35:01)




Now, let us discuss about the next test which is the purity test. Of course, it is of interest that the bitumen which is used in the construction should be in its pure form. So, how do we judge whether a bitumen is in its pure form, this can be done by a solubility test on bitumen, what is actually done that the bitumen is dissolved or is diluted in carbon disulfide or trichloroethylene.

So, in these two solvents pure bitumen is entirely soluble. So, what we do we take a bitumen of known weight, we dissolve it in the standard solvent and after that the solvent is filtered through a glass fiber pad, whatever material is left on the glass fiber pad is washed, dried and it is weighed. And we have to ensure that the purity of the bitumen is at least 99% If it has to be used for paving applications.

(Refer Slide Time: 36:02)

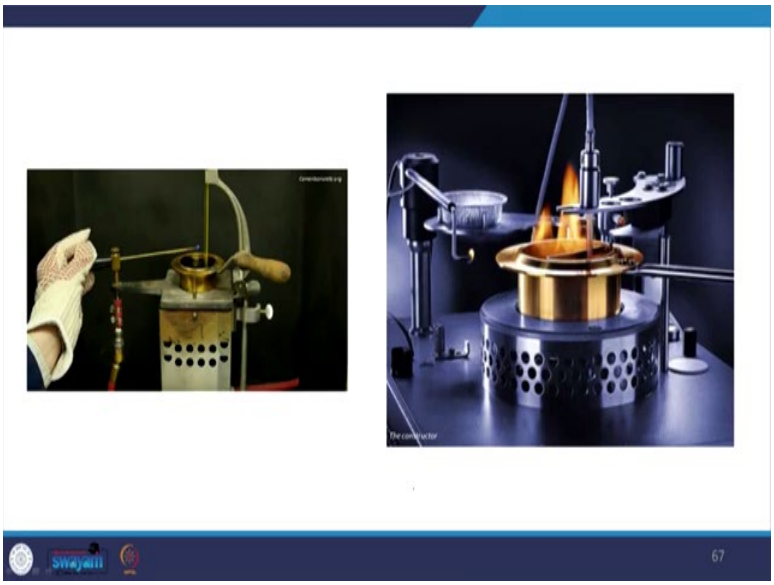



The final test in our list is the safety test. safety test is done to ensure safe working conditions when workers are heating the bitumen at the site to very high temperature. This safety is quantified using two parameters. The first parameter is the flashpoint of bitumen, and the second parameter is the fire point of bitumen. And the flash and fire point can be measured together using the Cleveland Open Cup apparatus.

What is done here that we have a cup a brass Cup, which is filled with bitumen and then we continuously heat the sample and in between we bring a small flame and pass it over the surface of the cup periodically. So, when the temperature of the bitumen will become very high, typically more than 200 degrees Celsius, it may happen that the vapor which is released, it will flash.

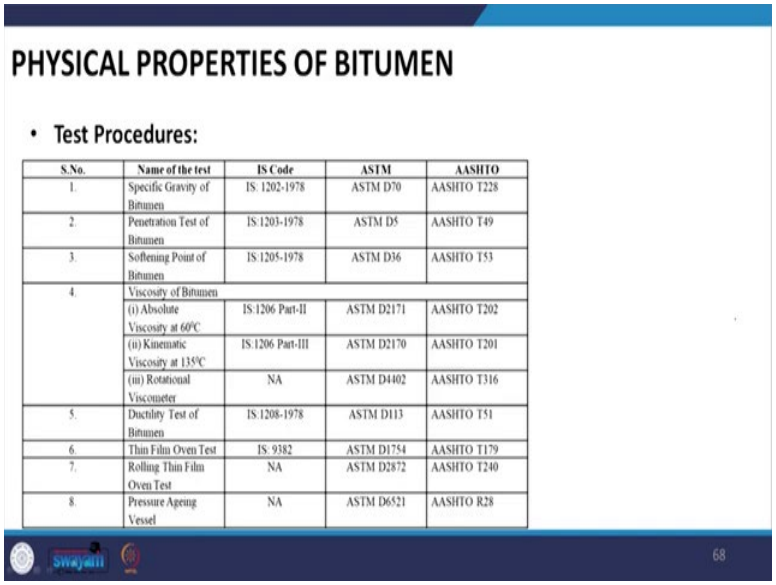
So, that particular temperature, where the vapor of the bitumen flashes is basically the flash point of the bitumen fire point is a temperature little higher than the flash point where these vapors will actually combust, and it will catch fire. So, for the safety both the flash point and fire point are reported, and we have to ensure that whenever workers are working in the field, they should not heat the bitumen to a temperature which is as close to the flash and fire point of the bitumen.

(Refer Slide Time: 37:37)




So, these two pictures are some typical pictures, which shows the Cleveland Open Cup apparatus and the procedure of flash and fire point adopted in the laboratory.

(Refer Slide Time: 37:52)




| S.No. | Name of the test | IS Code | ASTM | AASHTO |
|---|---|---|---|---|
| 1. | Specific Gravity of Bitumen | IS: 1202-1978 | ASTM D70 | AASHTO T228 |
| 2. | Penetration Test of Bitumen | IS:1203-1978 | ASTM D5 | AASHTO T49 |
| 3. | Softening Point of Bitumen | IS:1205-1978 | ASTM D36 | AASHTO T53 |
| 4. | Viscosity of Bitumen | | | |
| | (i) Absolute Viscosity at 60°C | IS:1206 Part-II | ASTM D2171 | AASHTO T202 |
| | (ii) Kinematic Viscosity at 135°C | IS:1206 Part-III | ASTM D2170 | AASHTO T201 |
| | (iii) Rotational Viscometer | NA | ASTM D4402 | AASHTO T316 |
| 5. | Ductility Test of Bitumen | IS:1208-1978 | ASTM D113 | AASHTO T51 |
| 6. | Thin Film Oven Test | IS: 9382 | ASTM D1754 | AASHTO T179 |
| 7. | Rolling Thin Film Oven Test | NA | ASTM D2872 | AASHTO T240 |
| 8. | Pressure Ageing Vessel | NA | ASTM D6521 | AASHTO R28 |

Now, since we have discussed many physical properties of bitumen, the different codes, the IS code, the Indian Specification Code, corresponding ASTM code and the AASHTO code they are listed in this table. And if anyone is interested, you can just download these codes or purchase these codes if required. And you can look at the procedure which is adopted in the laboratory to carry out different tests or to evaluate the different physical properties of the bitumen, which we have discussed.

With this, we come to the end of this presentation. And in the next lecture, we will start discussing about the viscoelastic properties of the bitumen. And we will also see some of the rheological experiments which are carried out to quantify the viscoelastic properties. Thank you.