Pavement Materials
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Lecture: 58
Overview of Alternate Pavement Materials (Part-1)

Hello friends, today, we are going to start and probably we are also going to complete the last module in this lecture series, where we are going to talk about alternate pavement materials.

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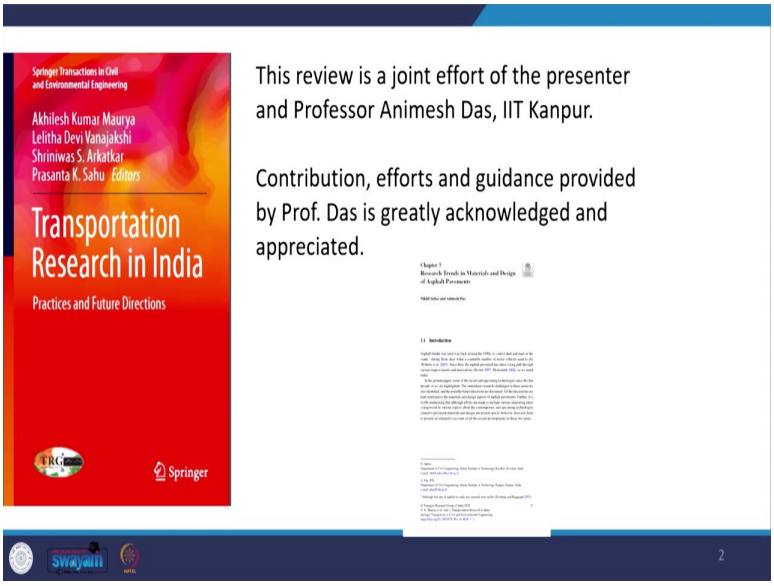

The contents of this particular lecture has been taken from a review work that was done by myself and professor Animesh Das from IIT Kanpur. And the same has been published in transportation research in India as one of the book chapters, which talks about practices and future directions in the area of transportation engineering.

While writing this paper, the idea was to list down various technologies, various recent trends that are related to materials and design of asphalt pavements specifically, but today, we will also talk about some of the recent advances or recent trends related to alternate materials that are used in the area of concrete pavements. Before we begin, I just like to thank Professor Animesh Das from IIT, Kanpur.

Without whose guidance and efforts, this particular paper would not have been possible and his efforts and continuous guidance is greatly acknowledged and appreciated. So, in this particular module, again, we are not going to talk very exhaustively, different pavement materials or alternate pavement materials

that are being used round the globe that are being developed around the globe. Because, if you remember I already mentioned in one of my lectures, that the area of pavement materials is watched, if you see the present scenario.

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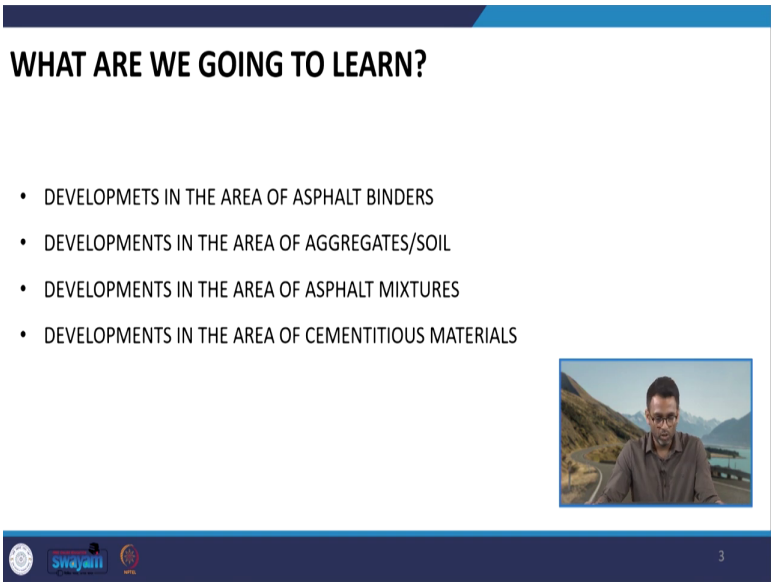

Each and every day, we have new materials that come up. Each and every day researchers are trying to use alternative materials in pavement construction and this researches it is continuously going on and it becomes difficult to summarize these developments in a particular module or through some lecture.

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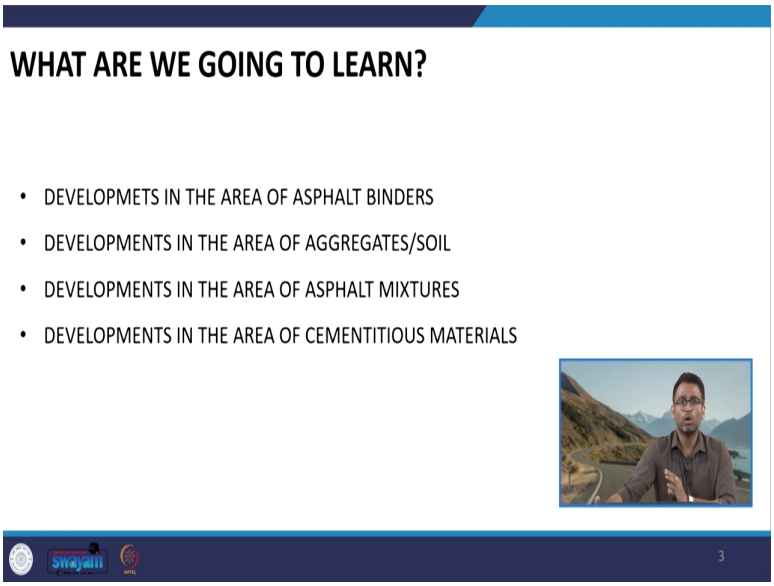

So, here the idea for this particular lecture is to list down some of these materials that are being used in the construction of pavements flexible as well as concrete pavements. And we will talk very briefly about these materials as we move forward.

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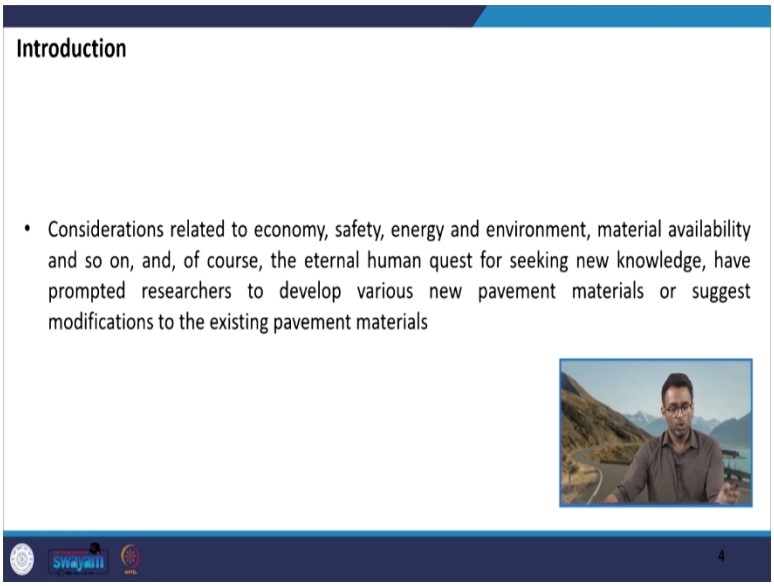

Sothe first question, which comes to the mind is why we need to use or develop alternate materials. As we have been discussing throughout this lecture series, that the conventional pavement materials, most of them are acquired through natural resources. Most of them are derived from fossil fuels.

And with the exponential growth in infrastructure and the need of building infrastructure, it has led to the depletion of these resources. It has led to increase in the emission of carbon dioxide in the environment. And therefore, there is a need which is felt by government as well as the highway agencies to use or develop materials that are more environmentally friendly and that can be more sustainable as well.

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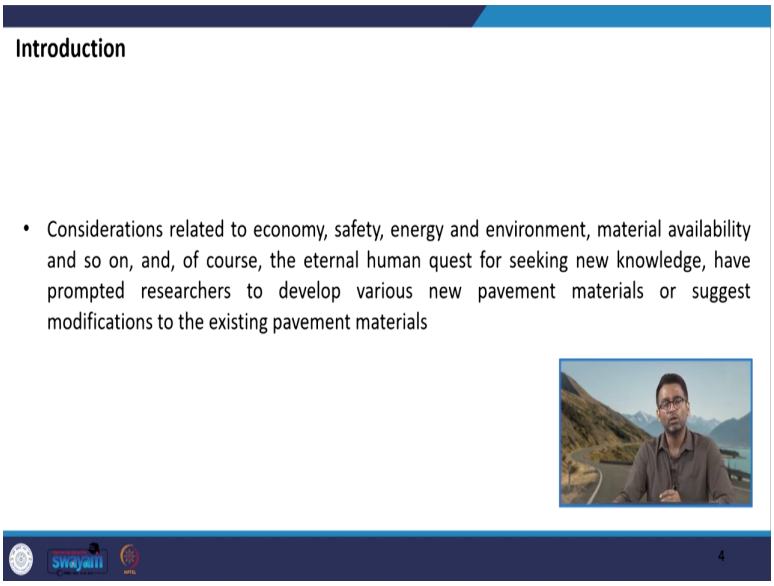

So, considerations that are related to economy, safety, energy and environment, also material availability and several other factors has led to the development of new pavement materials and also has led to the development of technologies that modify the existing materials, so, that we can optimize its use. So, there is always an eternal human quest to learn new things, to develop new things and to see if these new materials that are being developed can be successfully applied in various practices.

With this, let us start to talk about some of these materials, which recently have been very popular, especially when we talk about their use in asphalt pavements as well as concrete pavements. So, we will start talking about the asphalt materials related to asphalt pavements first and then we will conclude by talking about the developments in the area of cementitious materials as well.

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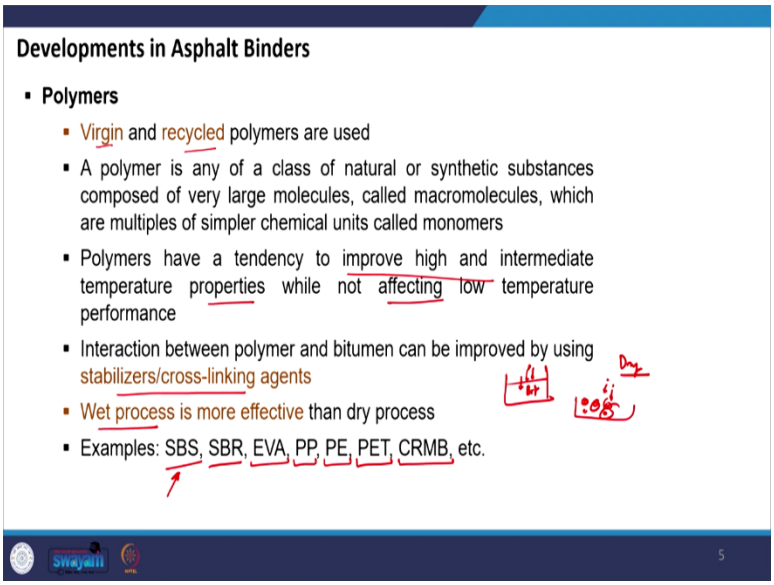

So, if you talk about the development in asphalt binders, various technologies can be listed. For example, use of polymers, we have already discussed about polymer modified binder what are they, but, these polymers in different forms are being developed and are being used at varying dosages to improve the rheological response, to improve the mechanical response of asphalt mixtures. Polymers are being used both in virgin and in recycled form.

So, for example, if you talk about plastic, we have waste plastics, we have virgin plastics. Similarly, there are several other polymers and which can be basically categorized into two broad domains, let us say, we have elastomers and we have plastomers. So, several elastomers and plastomers have been experimented and have been very successful also as a modifier for asphalt binder.

So, polymers they usually have a tendency to improve the high and intermediate temperature properties while they are also developed such a way that once they are incorporated in the asphalt mixture or the asphalt binder, they should not affect the low temperature performance as well. If you see the history of the development of polymers, it is not new various polymers were experimented over a period of time.

But then there were several issues related to the use of polymers, especially when we talk about the wet modification of asphalt binder using elastomers in plastomers. Due to the difference in specific gravity that is density between the modifier and the binder and due to the physical interaction rather than chemical interaction. These polymers were not found to be easily dispersive in the bitumen system.

So, technologies grew, people started to work on these issues and over a period of time, many stabilizers as well as crosslinking agents have been developed, that can improve the interaction between polymer

and bitumen. Incorporating polymers in the bituminous mixture, the asphalt mixture, there are various methods.

So, we can either go for a wet modification process where we are adding the polymer in the bitumen and we are creating a new binder here or else what we can do while preparing the asphalt mixture, we can incorporate these polymers during the preparation of asphalt mixture. So, this is the dry process. Literature say that, when we talk about polymer modification wet process is more effective than dry process. So, this is a more popular technique.

There are various examples of polymers. For example, SBS is one of the very popular polymers that is successfully used for improving the properties of bitumen. SBS stands for styrene butadiene styrene. We have styrene butadiene rubber under the plastomer category. One of the very popular plastomers is ethylene vinyl acetate, EVA.

We have polypropylene, we have polyethylene, we have polyethylene terephthalate, the one which we get in normal drinking bottles. Researchers have also used CRMB as in the bitumen modification process. So, this is some of the very brief characteristics related to the use of polymers.

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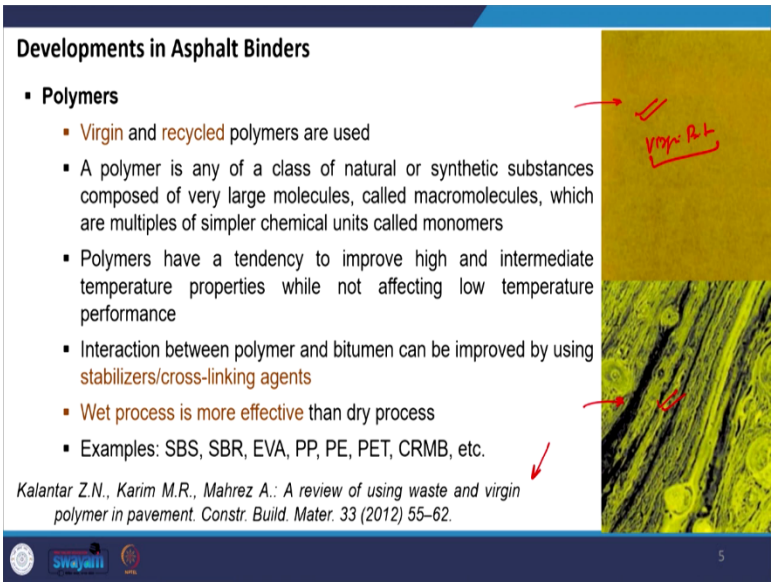

In this picture, you can see that this shows the microstructure of two different binders. So, this is what you see when you have only the virgin bitumen. So, a virgin bitumen under a fluorescence microscopy will look something like this. And then you can see here a picture of bitumen modified with a certain polymer and you can see a very cross linked state of the base bitumen with the polymeric system. So, these techniques are usually used to see the compatibility of the bitumen with the polymeric system.

In this particular lecture, I have also tried to include the respective reference from where most of the details of any particular slide has been taken. So, you can visit this paper and then you can get to know more about these topics which we will be discussing today.

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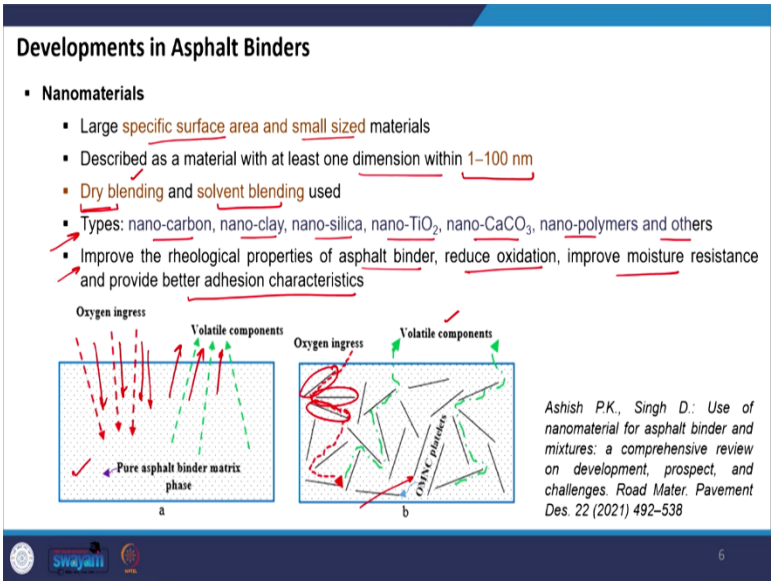

Then, we have nanomaterials again something which is becoming more popular when we talk about bitumen modification. Nanomaterials has some specific characteristics. For example, they have high specific surface area that is surface area per unit volume is very high. They are small in size. When we talk about the size the nano terms itself tell us that the size is very, very small up to the unit of as low as 10^{-9} meters.

And when we define a nanomaterial, at least one dimension should be within 1 to 100 nanometers. Nano material can also be incorporated either through dry blending where they are directly added to the binder or through solvent blending where they are first dissolved or blended with a solvent and this solvent is further used to modify the bitumen.

Various types of nano polymers have been experimented in the area of asphalt mixtures. We have nano carbon, nano clay, nano silica, nano TiO_2 that is titanium dioxide, nano $CaCO_3$, nano polymers and various other nanomaterials. And some of the disadvantages of nanomaterials are it is not very easy to synthesize these nanomaterials in the laboratory. It takes a lot of effort a lot of high end equipment's to synthesize these materials, then the cost of the nano material is also very high.

So, therefore, in industry people are always skeptical about its use, because the cost of modification increases. So, again researches are being conducted where people are trying to see or produce nanomaterials at a relatively lower cost such that they can justify the economical modification of the bitumen and the asphalt mixture. Nanomaterials have been found to improve the rheological properties of asphalt binder.

These are some of the positive aspects. They reduce oxidation, which means they reduce the aging in the binder. They improve moisture resistance and also they provide better adhesion characteristics. So, these attributes these advantages, it makes nanomaterial as one of the very attractive technologies especially when we talk about bitumen modification. This picture shows the mechanism through which let us say the aging can be reduced.

So, you see when you have a normal binder when oxygen ingress in this phase, so, they have direct path to come in and attack the bitumen. Similarly, the volatiles are the lighter components in the bitumen are free to move whenever the temperature increases, but when you have nanomaterials they interfere with these processes. For example, you can see the path of the oxygen ingress is hindered by the presence of the nanomaterials within the bitumen system.

Similarly, you can see how the volatile components find it difficult to go out once the temperature is increased, because of the presence of these nano platelets. So, this is the review paper which you can refer for more details about the use of nanomaterials in asphalt mixtures.

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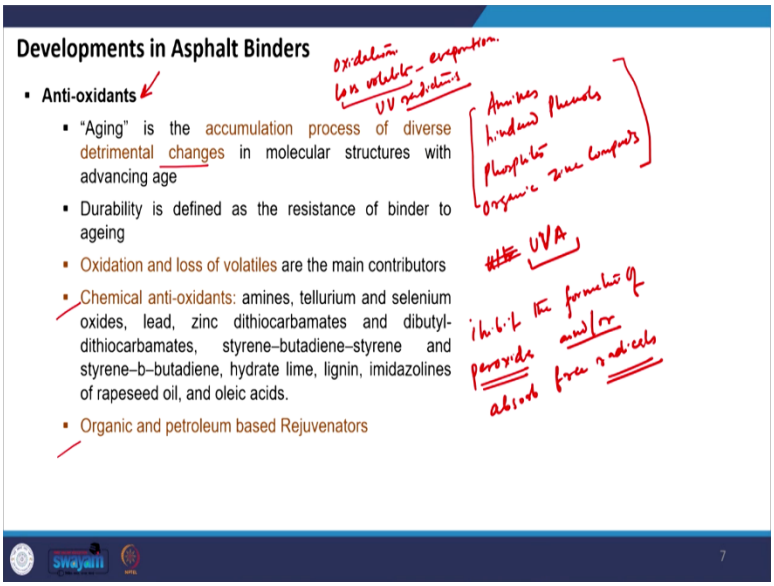

Then, we also have antioxidants. So, antioxidants are basically materials that helps us to improve the resistance of bitumen towards aging and we have already discussed in detail about the aging phenomena, which is the accumulation process of diverse detrimental changes. And these changes are built in because of probably oxidation, loss of volatiles.

Here when we say loss of volatile it is been evaporation of the lighter components and then we have effect from UV radiations also, which is a long term process once the bituminous mixture is laid in the pavement and because of UV radiations further aging of the mixture can take place. So, we have several categories here. We have chemical antioxidants.

We can also use organic and petroleum based rejuvenators to improve the resistance towards aging. When you talk about antioxidants, some of the very commonly used are amines, we have hindered phenols, we have phosphates, we also have organic zinc compounds that are being used. And we have also another category which is called as ultraviolet absorbers UVA.

So, these are again some of the materials that can be used to increase the resistance of the binder against aging. And ultimately, what is the mechanism on which these modifiers or these agents work? They inhibit the formation of peroxides which further leads to aging and or they have a tendency to absorb free radicals such that oxidation of the binder can be restricted. So, this is about the different antioxidant materials that are being used.

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Well, this picture shows that we have two types of aging, I am not going to discuss because we have already discussed in detail about short term aging and long term aging. And I hope by now we understand both

these forms of aging. So, this is the paper you can refer to which is related to the aging phenomena and bitumen. And they also have given much information about the use of different antioxidants that are used or can be used as agents to reduce the aging susceptibility of the asphalt mixtures.

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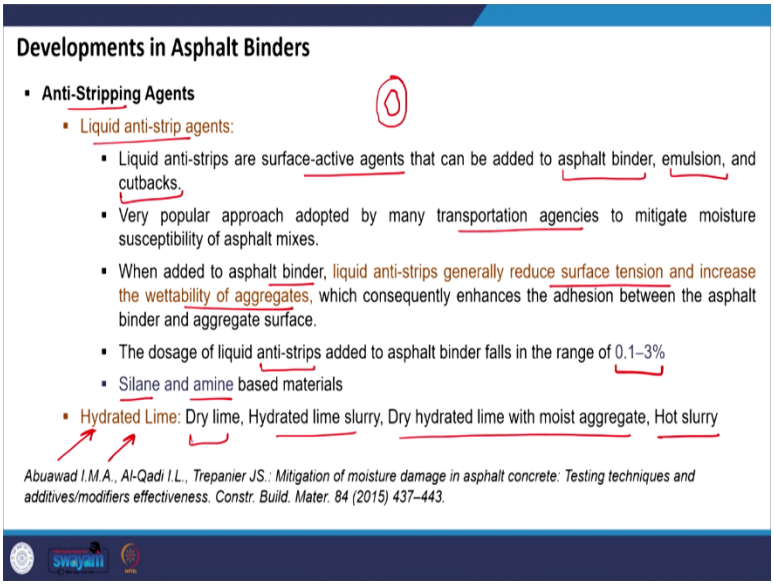

We also have anti stripping agents. So, this is used to resist moisture damage in the asphalt mixtures. Again anti stripping agents can be of different types. We have commonly liquid anti stripping agents are used. So, this liquid anti strip agents they are surface active agents that can be added directly to the asphalt binder, it can be added to emulsion or it can also be added to cut backs if we are talking about cold bituminous mixture as well.

These are very popularly adopted by various transportation agencies to mitigate moisture susceptibility of asphalt mixtures. So, when they are added to the asphalt binder, what happens that they reduce the surface tension and the increase the wettability of aggregates. So, they are almost linked to each other, because, if I am trying to wet a surface with another material, there will be an inherent resistance to this wettability.

So, if and this is because of the individual surface energy properties, so, if I reduce the surface tension between these two materials, the bitumen will easily wet the aggregate surface and this will also lead to better adhesion or higher resistance towards moisture damage. The dosage of liquid anti strip agents usually falls in the range of 0.1 to 3 percent.

And these liquid anti strip agents are either silent based or amine based materials. So, there are various materials but originally they are either silent based or amine based. One of the very popular anti stripping

agent is hydrated lime. So, if you talk about hydrated lime it is one of the most conventional anti stripping agents in fact and has been found to be very successful in providing resistance towards moisture damage in most of the cases.

So, in fact hydrated lime can also be added in different forms. We can add dry line, we can add hydrated lime slurry, we can add dry hydrated lime with moist aggregate again the reaction will lead to the formation of further products. Some researchers have also added it in the form of hot slurry and the process of addition will also finally affect the extent of resistance to moisture damage the hydrated line will provide.

So, it is important that we have to decide which process should be adopted. So, this is one of the papers you can refer to for knowing more about the moisture damage in asphalt mixtures.

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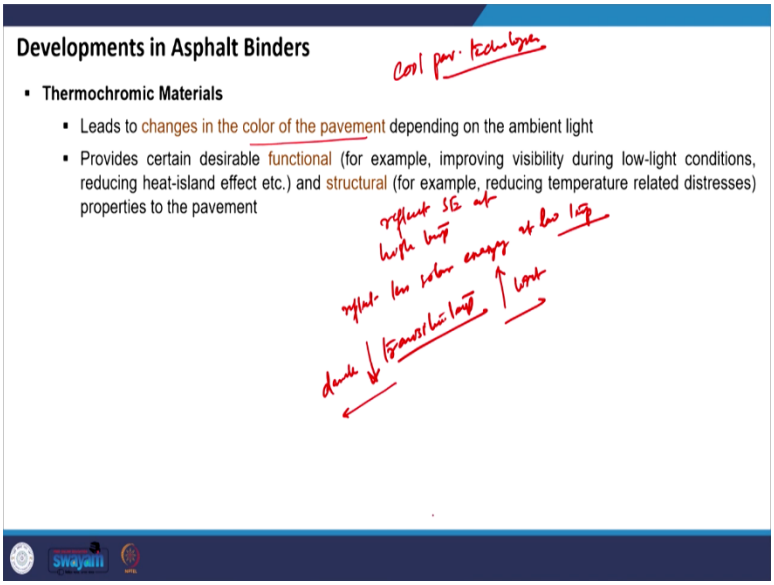

Another interesting material that can be used are thermochromic materials. So, these materials will change the color of the pavement depending on the ambient light. So, these are materials that have higher reflectivity as well as emissivity to solar radiation. Now, other than thermochromic materials, there are other materials as well, that has high reflectivity.

And MCT characteristics and these technologies we call them cool pavement technologies. But it can happen that some of these technologies can lead to low temperature distresses. So, thermochromic material what they do, what is the advantage that they will reflect solar energy at high temperature, and they will reflect less solar energy at low temperature.

So, This can happen by changing the color, the surface color of the pavement surface. So, try to understand that if you have a very dark surface, it will have a tendency to absorb the heat. If you have a light surface, it will have a tendency to reflect the solar energy or reflect the radiations that are coming.

So, in the daytime or in the summers when the temperature increases, I want my pavement to look lighter and when the temperature falls down, I want my pavement to have dark characteristics. So, that the stiffness properties can be maintained at both the temperature ranges. So, these materials they have some specific transition temperature. So, what happens that below the transition temperature they will become dark and when the transition temperature increases, they become light in color.

So, this way they are able to also provide resistance towards distresses that are related to high and low temperature in the asphalt pavement. And they are typically used at a rate of almost 5 to 6 percent by weight of the binder.

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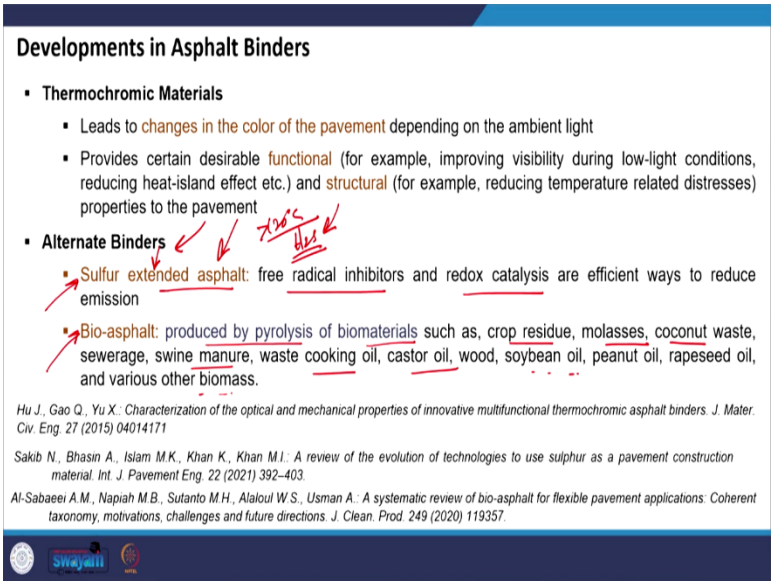

Then, researchers are also trying to explore avenues for alternate binders, because we understand that bitumen is a petroleum product, crude oil prices are rising. And it is all it is derived from a non-renewable energy source. So, therefore, various attempts have been made and are being made to use binding agent in the asphalt mixtures that are not from petroleum origin. One example is sulfur extended asphalt.

The problem with sulfur extended asphalt is that when you heat sulfur to a very temperatures typically greater than 120 degree Celsius, there is an emission of H2S gas which can be very harmful. So, this is one of the disadvantages that this technology did not become very popular. However, there have been

researchers that have tried to reduce the or have tried to find effective ways to reduce the emission of H2S gas.

So, they have used free radical inhibitors. They have used redox catalysis process where using which the emission of H2S gas in SCA or sulfur extended asphalt can be minimized. Another category in alternate binders is the use of bio asphalt. So, bio asphalt they are basically produced by pyrolysis process of biomaterials and various biomaterials have been used to extract bio binder, which have been used mostly as partial replacement of bitumen in the production of bituminous mixtures.

And this bio binder can be derived from biomaterials such as crop residue, molasses, coconut waste, we have swine manure, waste cooking oil, castor oil and you can see a lot of other biomass have been explored. And again these are some of the important references that can be explored to know more about thermochromic materials and also alternate binders.

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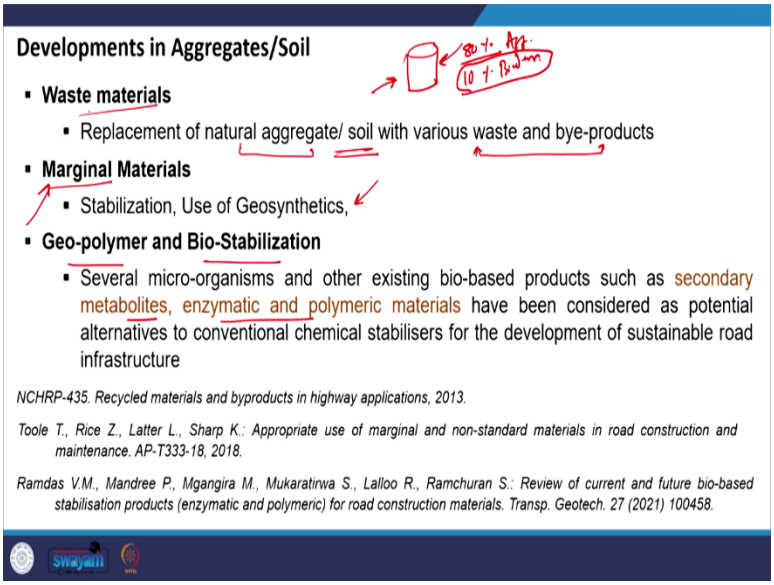

With this now, let us shift our discussion towards developments in aggregates and soil. It is very interesting to note that the researches that have been done in asphalt materials and asphalt binders are more in comparison to the parallel researchers that have been done in the area of aggregates and soil. And this is not surprising because if you look at the asphalt mixture, though the volume has almost like 80 percent of aggregates and 70 to 80 percent aggregates.

And let us say 10 to 12 percent binder, but the cost of this small percentage, if you see the cost of the bituminous mixture 70 percent of the cost is because of the presence of bitumen which makes it a very

critical and important material. And also, when we talk about the performance of asphalt mixture, the response of this mixture is a direct function of the biological properties of bitumen.

So, it is also on one hand not very surprising, that a lot of effort has been put, to research about bitumen more in comparison to other materials. When we talk about aggregates and soil, so people have tried to you use waste material as replacement of natural aggregate, because natural aggregate is obtained from natural sources.

And similarly, for soil also and various byproducts mostly from the industry have been used as a replacement of natural aggregate. Marginal materials have also been used. Marginal materials are those materials, which in their normal state do not meet the desired specification ranges as given by the highway agency. Let us say the impact value is very high or the Los Angeles abrasion value is very high and it does not meet the past criteria for its use in the construction of pavements.

So, these materials have been stabilized. People have used geosynthetics when they encounter marginal materials at the site to improve the performance of the asphalt pavement. Similarly, there are researchers that have been done on modification of soil using various geopolymeric material, various bio stimulation techniques.

Some of the bio based products include secondary metabolites, enzymatic and polymeric materials et cetera. These technologies are also considered as one of the sustainable methods to build a road infrastructure. Again, these are some of the references where details about these materials can be found.

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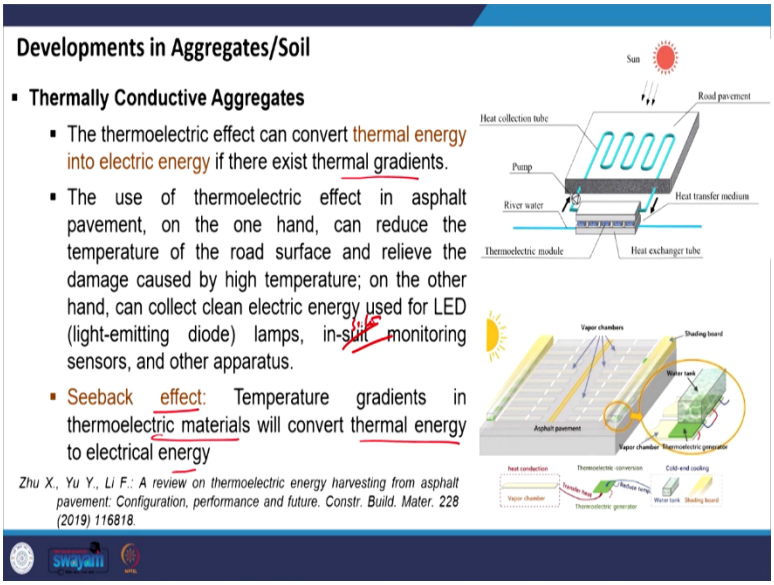

In the area of aggregates and soil people have also attempted to use thermally conductive aggregates. So, what are thermally conductive aggregates? These are aggregates that can convert thermal energy into electric energy which means, they have a tendency to absorb or they have high conductive ability and these conductive ability helps them to convert thermal energy into electrical energy.

But there has to be some thermal gradient and in fact, the use of the thermal conductive aggregates it works on the principle of Seeback effect, which says that if there is a temperature gradient in the thermoelectric material, it will convert thermal energy into electric energy.

And these technologies have been used for various purposes, for example, to reduce the temperature of the root surface and to relieve the damage caused by high temperature. It has also been used to convert the thermal energy into electric energy. So, that the same can be used for lighting purposes nearby the pavement system. It can also be used for in-situ monitoring of sensors and it can also be used for in-situ monitoring of sensors and other apparatus. Well, this is the reference which can be referred for more details.

So, we will stop here today and just to recap that we have discussed about the recent development and advances that have taken place in the area of asphalt binders and aggregates and soil. So, we will continue our discussion from here in the next class we will be talking about the similar developments that have taken place in the area of asphalt mixtures and cementitious materials. Thank you.