Introduction to Transportation Engineering
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Lecture - 24
Principles of Pavement Design

Hello viewers welcome to module four of this course pavement design. We are not starting with the first lecture in these module principles of pavement design. After we complete this course it is expected that the student will be able to appreciate the need for rational design of pavements.

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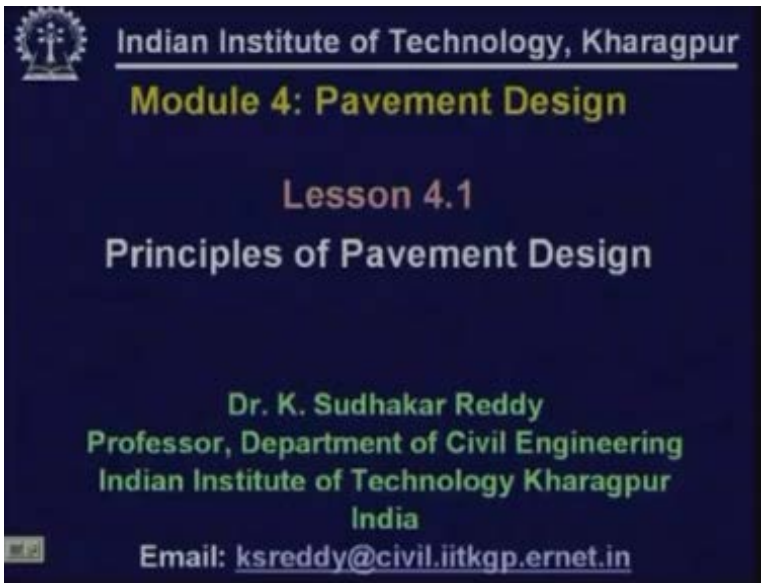

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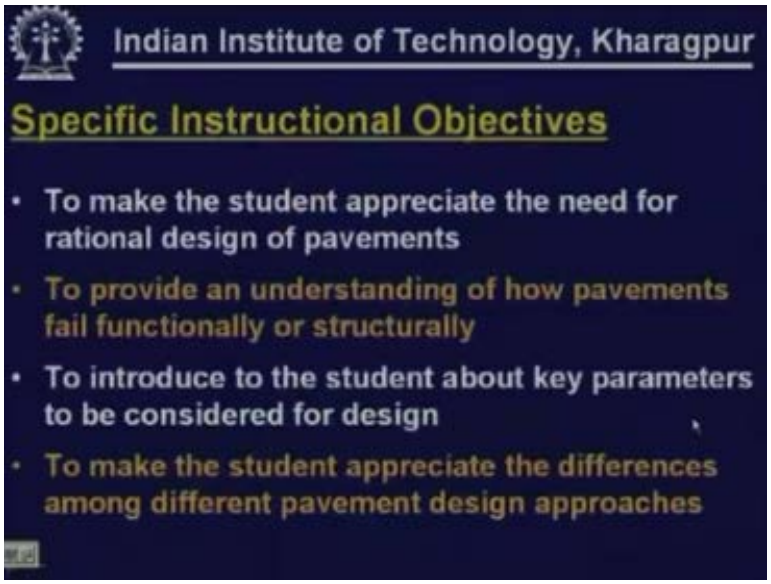

We underline the word rational because pavements can be designed by anybody, even ordinary laymen design pavements, they may not design pavements but they construct pavements. But for them to be designed properly, economically it has to be a rational design. And we also expect that through this course or through this lecture we would be able to provide adequate understanding of how pavements fail functionally or structurally. Rather we would hope that the students will be able to understand how pavements perform how different types of pavements perform under different conditions. We would also like to introduce to the students about the key parameters or design elements that are to be considered in designing pavements. And one of the other objectives of this course or this lecture is to make the student appreciate the differences that exist between different types of pavement design approaches.

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What is a pavement? Pavement is a structure that carries vehicular loading. We have to make sure that we do not confuse pavements with footpaths, walkways and other facilities that are used by pedestrians. We are often asked why we are designing pavements when they just carry pedestrians and which is not a significant load. So we have to understand that we are referring to structures that carry vehicular loading such as those exist in highways. These are built over prepared foundation or subgrade like most structures these are also built over foundations called as structures rather called as subgrade.

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Pavement normally has got different components. if you consider this to be existing foundation, existing soil or natural ground and if you want to build a pavement over this we would be preparing the top, this is a foundation either in cut or fill, would be preparing the top portion of this to proper specifications so that it attains adequate strength and that portion we call it as subgrade. The thickness of the top portion could be varying from three hundred millimeters to five hundred millimeter or it can be six hundred millimetre. Different agencies adopt different specifications accordingly thickness of the subgrade can be different. This is what we are referring to as prepared foundation. This has to be prepared so that it attains whatever maximum strength it can attain so that it has some desired specifications desired properties, and over this we place the pavement. These pavements carry either a stationary load or a moving load.

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We normally provide pavements for various facilities. They can be very wide ranging facilities such as airport pavements, haul roads, loading yards, bus terminals, highway pavements, we can have different types of highway pavements, we can build pavements for low volume roads and you have major highways wherein you can have main carriageways, you can have shoulders sub main carriageways, you can also provide pavements for service roads which run parallel to the major carriageways which carry normally low volume roads, very low volume volumes of traffic and so on.

We also have intersection areas to be considered where also you have to provide pavements. We can clearly see that all these are different situations. The loading that comes there is different, the loading that you get in terms of airport pavement is different from the loading that you get on a service road. similarly the axial configuration is different, the loading times are different, some of these facilities like haul roads you have very heavy loads carried, bus terminals, you may have stationary loads, in loading yards you may have stationary loads and highway pavements you may be having vehicles that move at very high speed and other places we have vehicles that move at very slow speed stationary so we need to take into consideration the magnitudes of loads, the variation in the loads that are carried, the speed at which the load is applied loading times all these parameters are to be considered for designing all these pavements. So naturally you cannot have a similar design procedure for designing pavements for all sorts of facilities.

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Depending on the importance of the pavement and loading that we are considering and also the climatic condition that exist at a given location normally we go for different types of or rather we adopt different types of pavements. These are categorized as unsurfaced roads where the surface is not sealed; we can have earth roads, gravel roads, moorum roads and other similar types of roads under this category. The main difference is that these are not sealed, the surface is not sealed and on the other hand you have surfaced or sealed roads wherein the pavement is sealed either by a bituminous surface or cement concrete surface or other types of treated surfaces. We can also have some unconventional pavements like block pavements, cell filled concrete pavements or which may neither be considered as unsurfaced roads or surfaced roads or it could be combination of different types of pavements.

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What you see here is a typical bituminous pavement. This is a section that is constructed on national highway 6. As you can see this is a dual carriageway road and this pavement was prepared over remindment over prepared separate it has got number of layers of granular material, it also had number of layers of bituminous material.

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This is a concrete road that was being constructed on national highway 60. In the centre you have the portion for central median and on either side you have a double two length carriageways and as you can see the concrete pavement here is also substantially thick. This is also prepared over or constructed over a prepared foundation called as separate.

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Here we have a block pavement. You might have seen such type of pavement at different facilities most probably for footpaths, walkways etc. but properly designed can also be constructed for low volume roads, you don't normally see them on very high volume traffic roads.

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There is a new type of road that is being constructed possibly for the first time in India called as cell filled concrete pavement. Here we have plastic cells which are being filled in with cement concrete.

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Broadly we categorize pavements as two different categories that are flexible pavements or rigid pavements. Under flexible pavements we consider earth roads, gravel roads, bituminous pavements and under rigid pavements we generally consider concrete pavements either plain concrete or reinforced concrete pavements.

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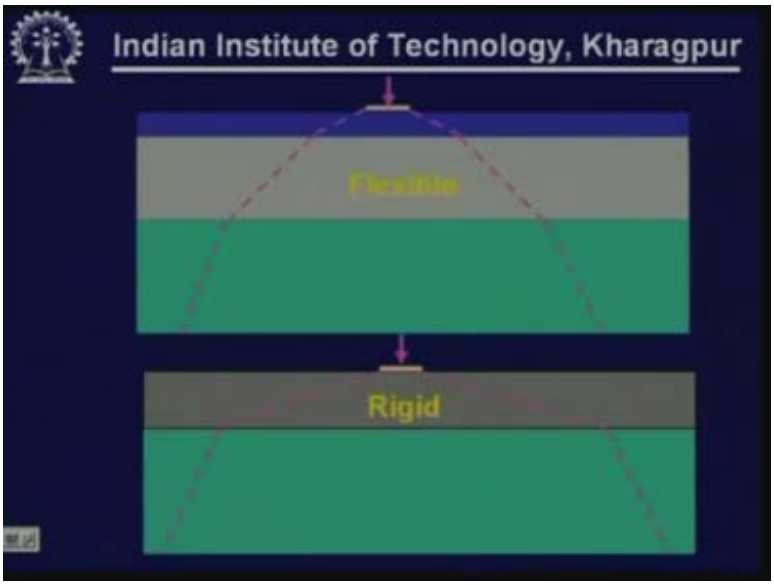

If you consider the flexible pavements normally we differentiate these two types of pavements in terms of their load spreading capability. The materials that we use and the layers that we provide in flexible pavements are in such a way that each one of the layers normally the upper layer is stiffer compared to the lower layers. So, as a result the load spreading capability gradually goes on decreasing. The load spread has to be done in such a manner that in each layer the stresses that are induced should be less than what can be handled by that particular layer. So ultimately when you come to the subgrade level the stresses that are there at any depth of subgrade have to be reduced to such magnitude that the

subgrade can handle. Same is the case for any other layer that you place above the subgrade. The stresses are to be properly distributed so you have to select proper materials and then adequate thickness of layers above the layer. But whereas when we consider rigid pavements most of the load spread is done by the concrete layer. As a result the foundation has not much of a role really to play in the case of concrete pavements as far as the load spread or load carrying capacity is concerned.

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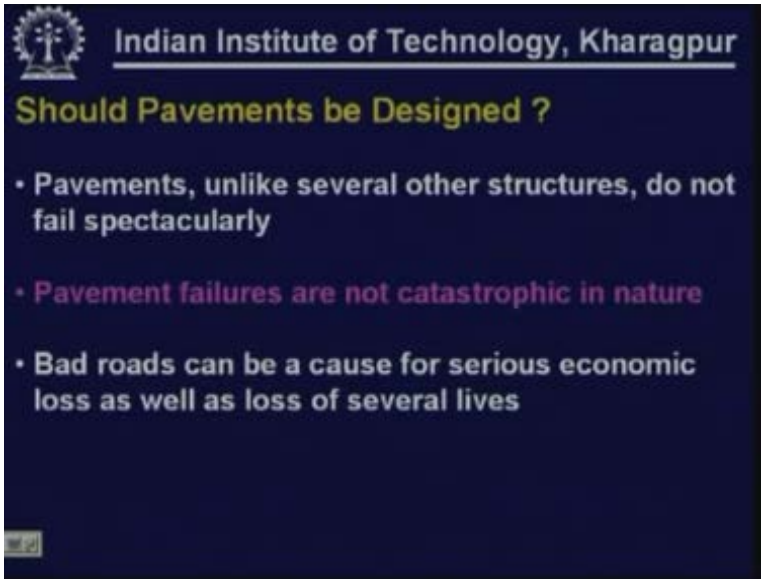

The question that should be asked is should we design pavements? Are they such important structures that require the attention of specialist pavement designers? The problem is that unlike many other structures pavements do not fail spectacularly. There not structural failures that cause so much of concern, so much of hue and cry, you would not see them failing catastrophically leading to loss of life within hours but they fail slowly over some time period but problem is that bad roads can cause very serious economic loss to the country. They of course cause lot of loss of lives but this is what we need to consider very seriously.

If you cannot design roads properly we would be wasting a lot of very important engineering materials and lot of other resources we have. you might be knowing that most of the roads that we are building for national highways now-a-days they cost almost something like 3 crores to 8 crores per kilometre that is a great deal of money. even the Pradhan Mantri Gram Sadak Yojana roads that we are constructing for village roads very low volume roads even those roads cost something around 20 lakhs to 30, 40, 50 lakhs depending on the number of cross ((00:13:11 min)) structures that you have over there. That's the kind of money we have to spend on roads now-a-days. This has to be done judiciously. As I said anybody can construct roads but you require great engineering skills so that this money that is spent is spent judiciously.

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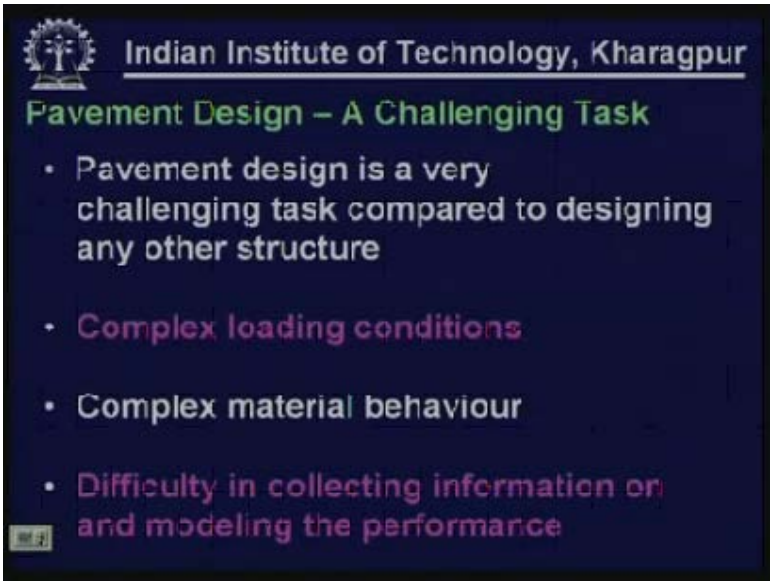

This is a very challenging task because of the complex very complex loading conditions that we have. It's not of course all other structures are subject to complex loading but we consider the loading that is subject on the pavements to be very complex in terms of the variations in magnitude, in terms of the variations of types of vehicles that are there, in terms of the frequencies that are different for different types of facilities and more importantly the materials that we are using for constructing these payments are very, very complex in nature we use soils, we use granite materials, we use bituminous materials, we use cement concrete, combination of all these materials in a one single pavement some of these materials are susceptible to temperature their behaviour is susceptible to temperature, susceptible to load that is applied, various climatic conditions, for most of these materials behaviour is non linear and we are having to deal with a combination of all these materials simultaneously and it is very difficult to obtain proper accurate information about the performance of these individual materials and the performance of the structure which consist of all these materials together. It is very difficult to model them either in the laboratory or on a field scale and then obtain accurate information about that behaviour. As a result it becomes a very challenging task to design pavements.

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What are the main design parameters that we have to select in designing any pavement? The first one is what is the type of pavement we are going to adopt in a given situation whether it is going to be concrete pavement, friction pavement, some other unconventional pavement or a combination of these things. Having selected a pavement type what are the number of layers, how many number of layers are going to be provided, what is a material to be used in each layer, what is the thickness of each layer to be provided and if you are talking about concrete pavements what is the joint spacing, what types of joints, whether it is reinforced, unreinforced and similarly various other design parameters are to be selected depending on the pavement structure that are different.

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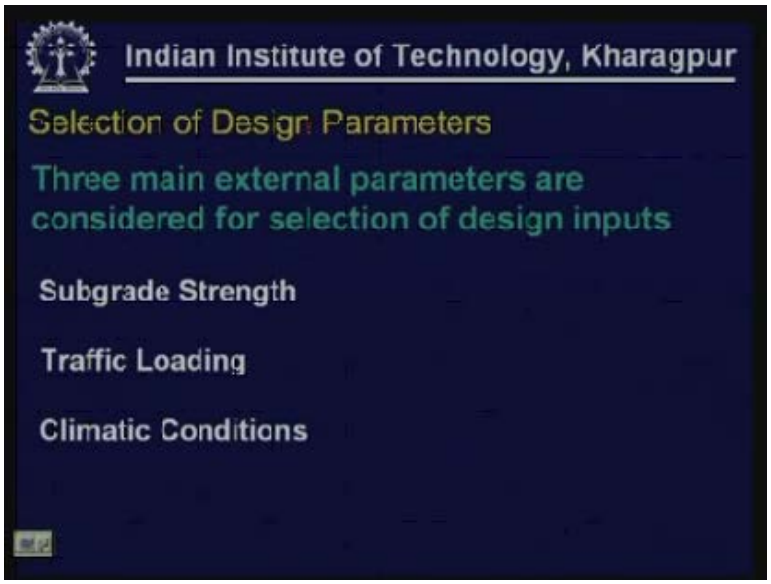

In selecting these design parameters such as thickness, type, type of pavement, number of layers and so on and so forth we have to basically consider three external parameters. These are parameters that are external to the pavement. The first one of these things is the subgrade

strength. What is the type of subgrade that we are trying to provide, what is a strength that this subgrade can mobilize and how we it take that subgrade strength into account in designing our pavement. The first external parameter that we have to consider is subgrade strength. The next external parameter is obviously the traffic load that is applied, how many numbers, what magnitudes at what intervals so this is another external parameter we have to have information about and third is the climatic condition. In terms of temperature in terms of rainfall how it varies over different seasons all these information is very essential for designing pavements properly.

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If you consider the first external parameter which is subgrade the subgrade can be prepared over embankment, once again subgrade is nothing but prepared foundation prepared to proper specifications. The subgrade can be over an embankment or it can be in cutting also. We are concerned about what is the type of soil that we are using and what is the strength that can be mobilized for this particular type of soil if it is properly compacted and properly prepared and at times we are also interested in what are the drainage characteristics of the subgrade material so we take into account all these parameters when we specify what is the type of subgrade that we are providing.

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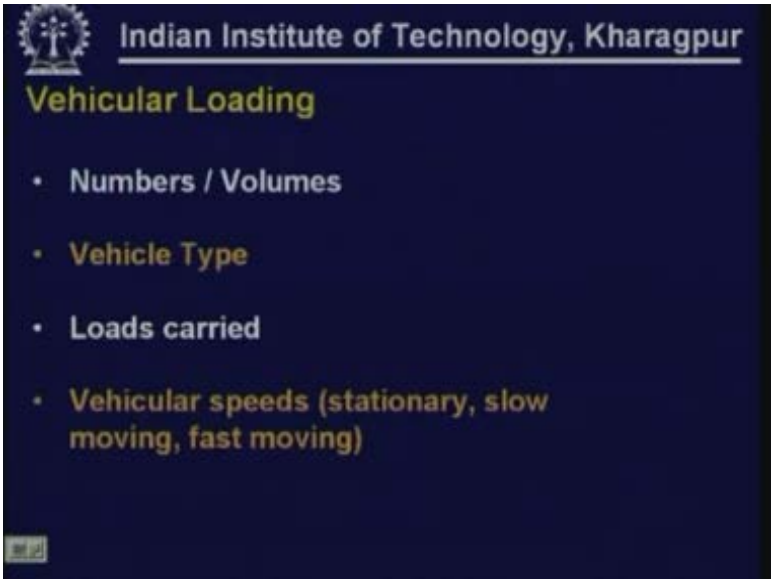

Similarly in terms of vehicular loading we are interested in numbers or volumes, how many vehicles per hour, how vehicles per day or how many vehicles that the pavement has to carry over its life period 10 years, 12 years, 20 years, what type of vehicles are going to be using this pavement; heavy vehicles, small vehicles, mostly empty vehicles what are the loads that they carry, are they very heavy, are they following legal elements, is there overloading, what is the speed at which these vehicles are following because depending on the speed the characterization of the materials is going to be different, the response of the pavement is going to be different depending on the speed of the load or speed of the vehicles so are these vehicles stationary, are we constructing pavements to carry stationary vehicles or are we going to have only slow moving vehicles at a given stretch of the road or given stretch of a facility or do we expect over a given stretch we are going to have only fast moving vehicles travelling at 60 Km, 100 Km or even more. So the designs are going to be different for each one of these situations.

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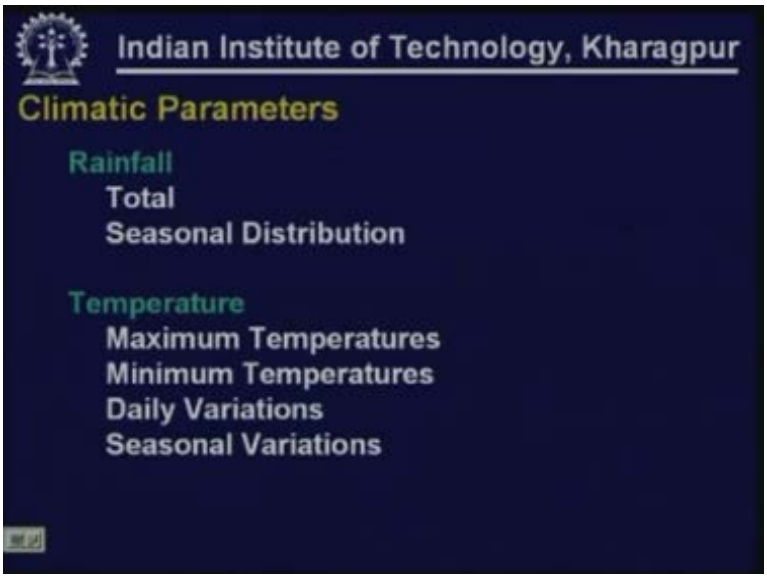

Coming to climatic parameters we have to consider about rainfall, what is the total rainfall that would be there in a year, how it is going to be distributed seasonally and we would also see how this rainfall is going to affect the performance of the pavement and affect the strength of different layers such as separate granular materials, how much of water is going to the pavement, how it is going to damage the bituminous layers and other types of pavements and we also need to be collecting information about what are the maximum temperatures the pavement is going to subjected to because materials like bituminous mixes are highly susceptible to temperature variations, they become very soft subjected to very high temperatures they can become very hard, very stiff subjected to very low temperatures so we need to understand the maximum temperatures and minimum temperatures the pavements are going to be subjected to and also the duration for which during which the maximum temperatures are going to be there and duration during which the lowest temperatures are going to be there, how the temperatures are going to fluctuate during the year, what is the daily variation, what is the seasonal variation all these things are important information or important parameters that we need to collect the information on.

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What is design? For any facility we may not be talking about pavement only it could be any other structure, it can be building or any other structural limit of a building being column or anything else. We need to select appropriate values of deign parameters. In the case of pavement these design parameters are layers, numbers, thicknesses, material properties. We have to select them appropriately in such a way that the facility pavement being column performed satisfactorily or in an acceptable manner. What is important is we are trying to select design parameters, thicknesses, material properties and so on in such a way that the pavement is going to perform performance is very important and it has to be satisfactory. So once again the keywords are design parameters that we have to select and performance. The pavement has to perform.

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The design variables that we have to consider are, this is the same thing that we listed earlier; pavement type, number of layers, material that we use in each one of these layers, thickness of each layer in the case of concrete pavements, joint spacing, reinforcement details and other such details.

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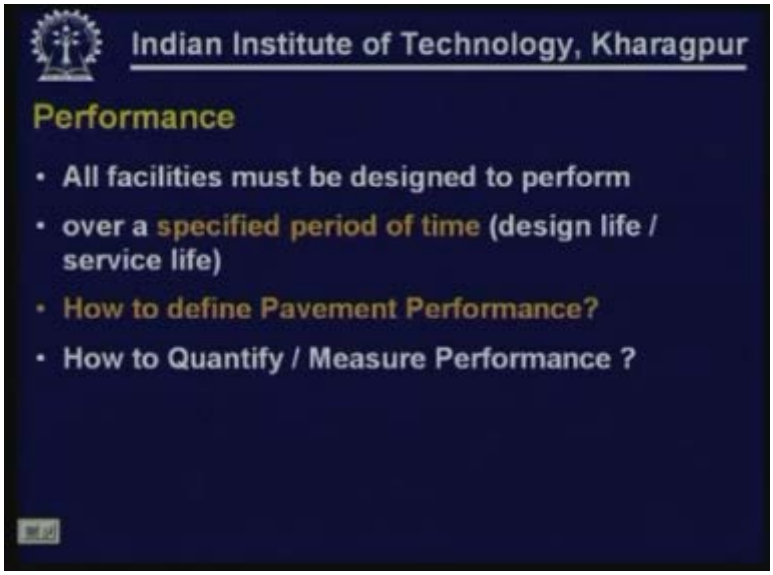

We mentioned performance and also said the pavement has to perform. for that matter all facilities must be designed to perform, they have to perform over a specified design period we call it as design period or service life period ten years, fifteen years depending on the importance of the road we may select twenty years and if it is of lesser importance we may select five years or ten years life period or service period so during this period the pavement has to perform satisfactorily. But problem is how do you define pavement performance and how do we quantify that and how to measure the performance of pavement.

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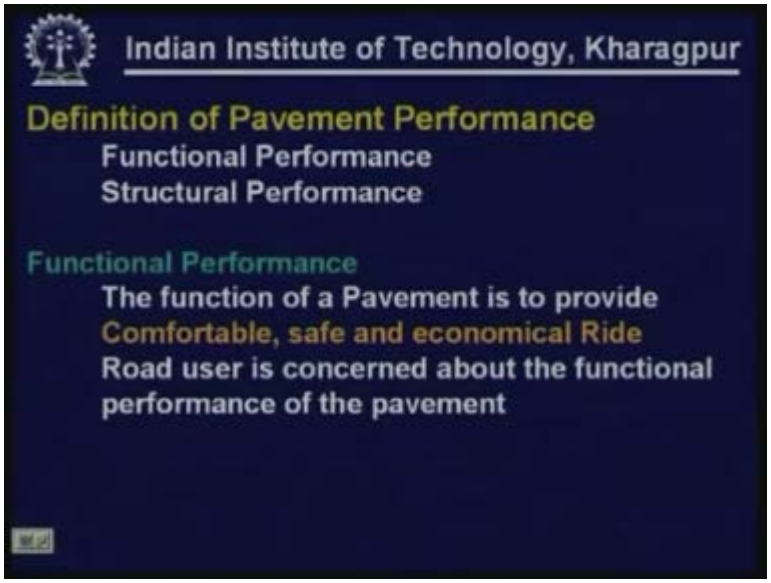

We normally talk about two different types of pavement performances. The first type is functional performance, second type is structural performance. Functional performance is taking into consideration the function of the pavement. What is the function of the pavement? The function of a pavement is to provide comfortable, safe and economical ride to the road user. This is what the road user is concerned about. He is really not bothered about what material is used, what is the strength of the material, what thickness was used as long as he is getting a comfortable ride, he is safe on the road and he is getting economical ride he is happy.

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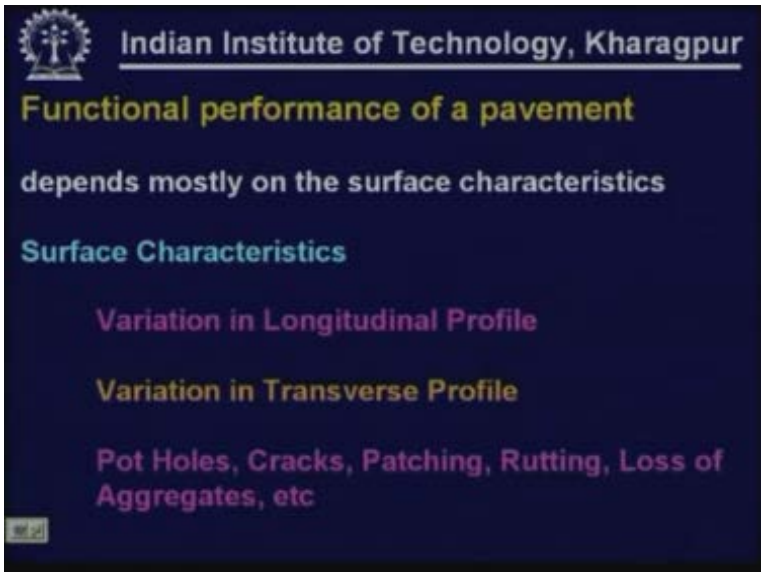

Therefore from the road users' point of view we have to take into account functional performance. Functional performance of a pavement would depend naturally on the surface characteristics. If we have bad surface characteristics if surface profile is varying we have pot holes, we have cracks we have various problems with the pavement surface, so that is going

to lead to uncomfortable ride, may be unsafe ride and also if you have uncomfortable ride, bad road profile it would also lead to uneconomical ride. So the functional performance mostly depends on surface characteristics such as variation in longitudinal profile, variation in transverse profile and also due to a presence of pot holes, cracking, patches, rutting, loss of aggregates and various other surface stresses that we can see on pavements.

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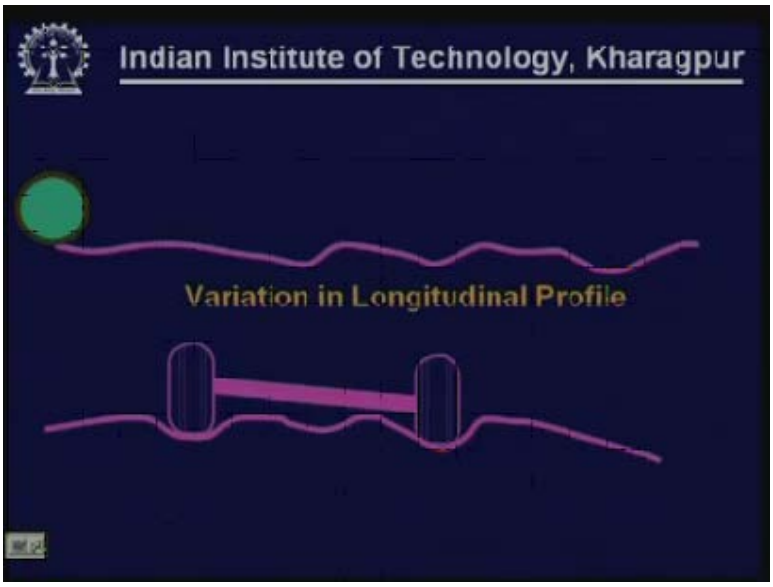

This is where you have variation in a given pavement surface in the longitudinal profile and if this is a wheel of a vehicle in which you are sitting you can visualize how uncomfortable you are going to be so this would clearly tell you that if you have variation in longitudinal profile you are in for an uncomfortable ride. Similarly, if your cross profile is undulating it's not properly done and if there is a vehicle that is travelling on that road you can see that there is going to be a swaying movement in the transverse direction and this can cause significant amount of discomfort and this can be unsafe as well.

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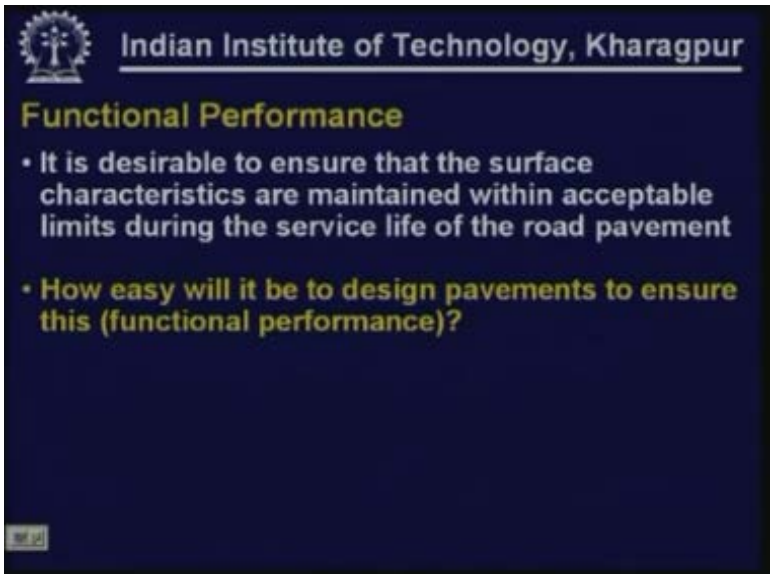

But it is desirable to ensure that the pavement and its surface characteristics are maintained within acceptable limits during the service life of the road pavement. That means if we are talking about a ten year life period or fifteen year life period. During that period the surface characteristics should be in such a way, it's always going to be not perfectly smooth there is going to be some variations that is going to come in but it should be within acceptable limit so as not to cause undue discomfort to the road user and undue safety hazard to the road users. But we have to ask one question. How easy will it be to design pavements to ensure this that is functional performance? Can we select thicknesses of pavements and material properties and other design parameters in such a way that the functional performance is issued? How easy is that going to be? It's going to be very difficult, we'll see that.

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We'll now discuss about the other type of structural performance and while we discus about structural performance we are in fact talking about structural failures. Most of this distresses or defects that we observe on pavement surfaces we talked about cracking, we talked about rutting, we talked about pot holes and other types of problems they are mostly caused by repeated application of loads, traffic loads or vehicular loads, most of them are caused by traffic loads and some of them are of course caused by non load associated factors such as some pavements fail even without an application of one single load, it can fail because of traffic, it can fail because of moisture, it can fail because of poor quality materials, improper construction practices and inadequate maintenance that we adopt.

There are also failures that are caused because of load associated reasons, there are failures that occur because of non load associated parameters. We have to decide these parameters that we are going to take into account when we design pavements, is it the load associated or non loaded associated parameters etc. Of course we have to take all these things into account but in what way we are going to consider these parameters.

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If a pavement shows load associated distress then it is considered to have a failed structure, then it is considered to have not performed satisfactorily and it doesn't have adequate structural performance. Structural performance is nothing but demonstration of its structural adequacy over sufficient length of period over design life period, it's not that the pavement has got adequate structural strength at the beginning of the service life period but over its entire life period it should have adequate structural strength. But how much is adequate after four years, how much is adequate at the beginning of the service life that has to be defined. The common forms of structural failures are cracking and permanent deformation.

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This photograph shows a pavement that has cracked, this is a bituminous surface, you see it is excessively cracked, this is mostly caused by load applications, we call this as fatty cracking this is caused by repeated application of loads but you can have cracking caused because of various other reasons as well.

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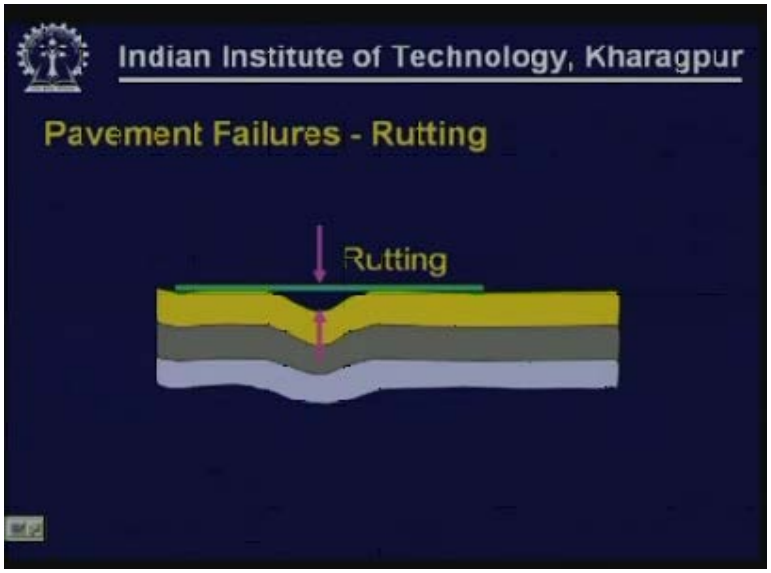

We see here rutting phenomenon that is occurring in pavements, this is a failure that occurs because of shear flow or permanent deformation of some of these pavement materials or all of these pavement materials. But most of this rutting normally occurs in the subgrade but it can occur in other layers also. But what is seen at the surface as rutting or rut depth is the accumulated permanent deformation that is occurring in different layers, the sum of all that is seen on the surface as rutting. Normally this occurs along the wheel path. Usually most of the wheels travel along a particular channelized manner and that is the portion which undergoes this rutting. So that's the path which would carry most of the wheels.

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This photograph shows another type of failure known as bleeding. You can see that bitumen has come up to the surface and you see patches of bleeded surface this could be because of over compaction of the pavement, pavements that are subjected to high pavement temperatures, pavements wherein the bitumen's mix was not properly designed, pavements

where you have very heavy loading that is applied to the pavement and so on. So this is another type of failure that is of major concern to the pavement engineers in the recent past.

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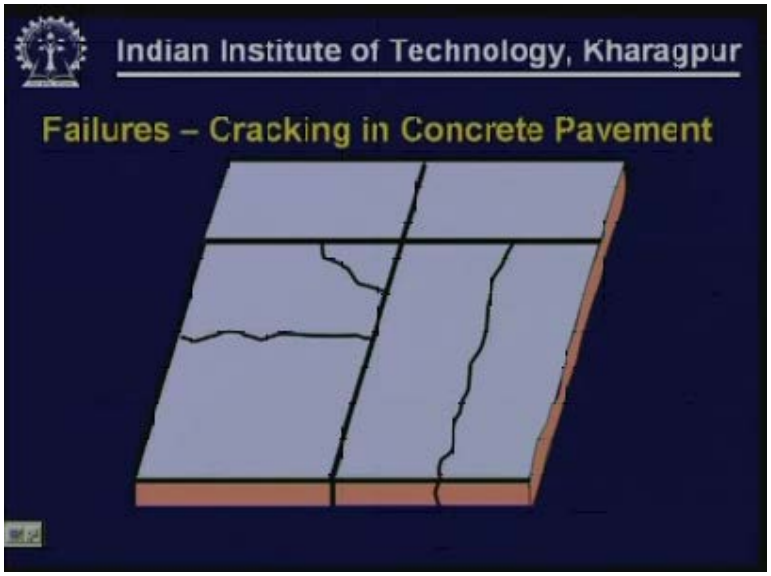

If you consider concrete pavements cracking is the most common type of failure that you see, it could be corner cracking, transverse cracking, longitudinal cracking but you may see all types of cracking in an old concrete pavement. Some of these cracks could be caused by loads, some could be caused by only temperature difference that you expect within the slab thickness or temperature variations that occur over long periods or for other reasons as well.

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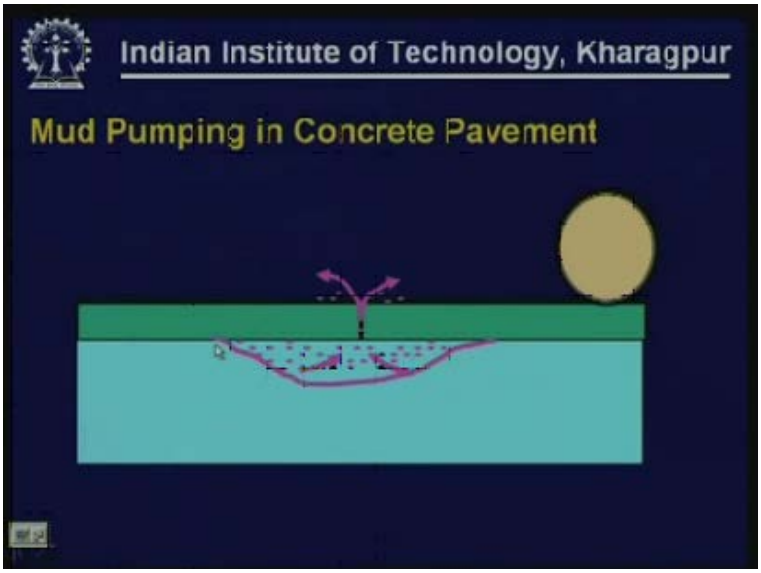

Another type of failure you may see in concrete pavements is what happens at the joint. If we have a fine grain subgrade and then if it is saturated and then as wheels go over this and as the slab deflects this should be pumping out the points through this joint over many repetitions of load that is applied and over several deflections of this slab at this joint the fine

material gradually starts getting replaced through this joint and then what we would subsequently have is a wide here so that could lead to loss of support here and then the slab will crack here.

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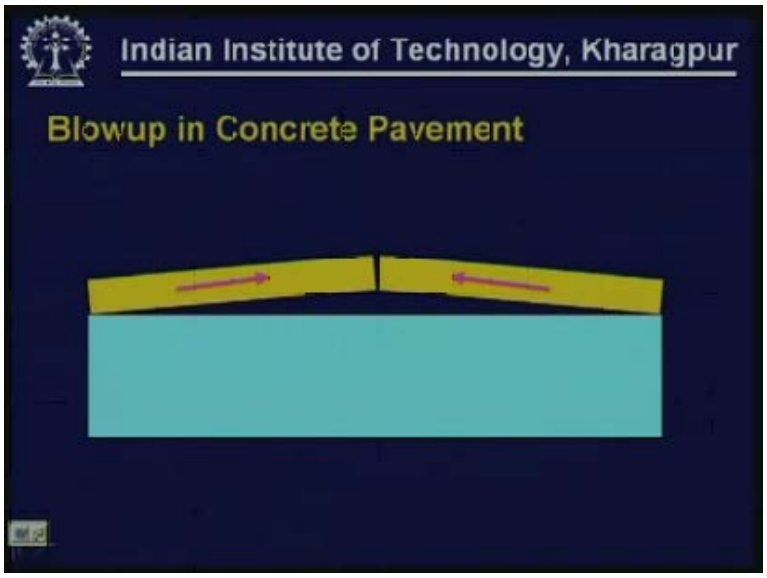

Another type of failure which is not very commonly seen is blowup in concrete pavement. Associated with increase in pavement temperature related to the temperature at which the pavement was constructed the slab was laid. If the temperatures exceed or increase significantly and if there is not adequate gap between these slabs or to account for the expansion of both these slabs then the slabs can either crush or they can do blowup like this.

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Again we will come back to the question of what to design the pavements for. We have seen that there are different types of failures for different types of pavements and we are concerned about functional performance of the pavement, we are also concerned about the

fact that the pavements have to be structurally adequate so should we design the pavement so that the pavements are acceptable functionally, or the pavements are acceptable structurally. For a road user functional performance is what matters. For a designer it will be very difficult to take into account to model functional performance and to correlate various design parameters exactly with the functional performance is usually very difficult. It would rather be easy for a pavement designer to design the pavements so that it performs adequately so that it has got adequate structural strength.

A road designed to give adequate structural performance we should expect that to perform satisfactorily in functional performance also. That means a structurally adequately designed pavement should be expected to be performing satisfactorily should be expected to give adequate proper comfortable riding, safe riding and then economical riding surface to the users provided whatever maintenance is required hardly any pavement is designed so that it's going to have no maintenance or zero maintenance during its entire life period.

Every pavement has to be maintained at regular intervals. Whatever is the associated maintenance that is required will be different for different pavements but every pavement has to be maintained unless we are trying to design what are known as zero maintenance pavements. Every pavement has to be designed adequately. If it is designed adequately we hope that it will have adequate functional performance as well provided it is maintained at periodical or regular intervals.

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There are different design approaches for designing pavements. Different agencies adopt different approaches. In India we follow a different approach, in America different states follow different design procedures similarly other countries other agencies have got different approaches that are relevant for their conditions, relevant for the traffic condition that they have and so on. These design procedures or approaches are usually developed on the basis of observed performance of the pavement. it is very important that any design procedure has to be on the basis of performance of the pavements that has been observed over sufficient length of time, sufficient number of pavements that have been observed how they behave that has to form the basis for any design procedure.

The observed performance of the pavements or the performance of a particular pavement as to why it is performing satisfactorily or why it is not performing satisfactorily has to be correlated to the design parameters that we have adopted or that exists in that particular pavement. Some of the parameters are; what were the thicknesses, what were the materials, why this particular pavement has performed satisfactorily, why another pavement has not performed satisfactorily and so on. So the satisfactory performance has to be correlated to the designed parameters that were adopted in that particular pavement and also may be the construction practices that were adopted etc.

So all these things will have to be taken into account and then whatever important parameters that is to be selected has to correlate with the performance. The relationship developed between the performance of the pavements and the design parameters that we have selected. We have to select what are the important design parameters that have a great deal of bearing on the performance of the pavements. So the performance has to be correlated to the design parameters and that correlation is called as performance criterion.

There could be a number of performance criteria, there could be just one criterion there could be set of criteria for a given pavement these criteria explain why a given pavement performs better compared to another pavement so they explain the relationship between the performance and the design parameter. this could be just in the form of an equation, set of equations, charts or it can be anything but they should explain why a pavement performs better and why another pavement does not perform so satisfactorily.

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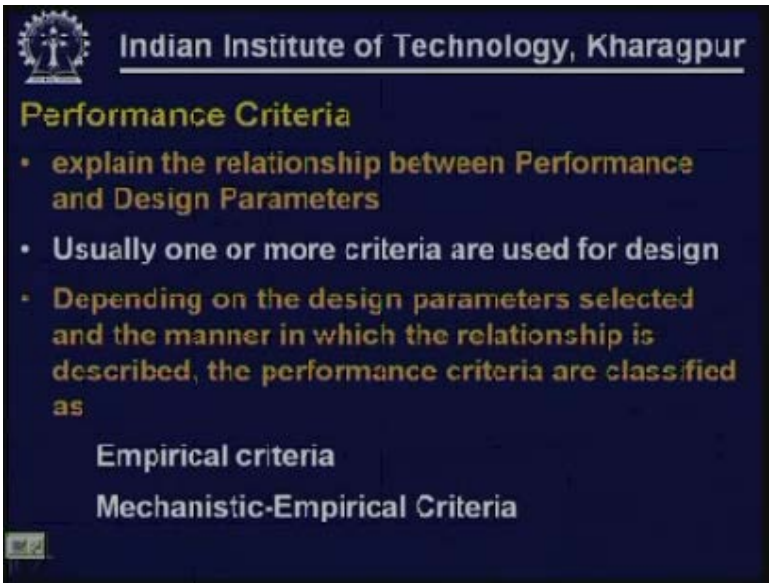

We normally have either one criterion or more than one criterion. Depending on the design parameters that we select and the manner in which the relationship is described the performance criteria are usually classified as empirical criteria or mechanistic empirical criteria.

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Empirical criteria: In this the performance of the pavement is correlated to some simple parameters like subgrade soil index, plaster index, liquid limit index or may be what is the maximum gradient that we can get in a compaction test.

California bearing ratio value: Some simple parameters that we can get corresponding to the subgrade or some other material properties. So the performance of the pavement is correlated to some of these simple parameters. Experience or performance is nothing but the observed service life. If a pavement has performed satisfactorily that means it has served for ten years or fifteen years or it carried so many numbers of vehicles so many number of standard loads satisfactorily. That performance is normally correlated to the pavement design parameters as we mentioned earlier. In the case of empirical design it is either the subgrade strength or thicknesses or a combination of the other parameters by statistical means.

The relationship does not explain the fundamental mechanistic behaviour of different materials used in the pavement. We normally take some simple parameters which really do not explain for example the California bearing ratio or the liquid limit or some other parameter of subgrade. These parameters normally do not explain what would happen to the material if it is subjected to a certain load either static load or reputed load. so whatever parameters that we select in empirical design procedure they are not adequate to explain the load verses stress strain behaviour of the material, different types of material so that we'll not been a position to take into account if we are going to go for empirical approach.

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As a result empirical methods cannot be extrapolated with confidence beyond the range of experience. naturally empirical design methods have been developed on the basis of experience that has been collected at some place or over different places from different pavement sections and that has been correlated to some simple parameters as long as similar conditions exist, as long as similar climatic conditions exists, similar traffic conditions are there we are using similar materials. More or less conditions are similar to the experience that was there then we can be confident that it worked there and it will work here. But once things start to differ from those conditions we will not be very confident.

The level of confidence that we attach with our design procedure or designs we give based on this design approach cannot be very high. These may not work for new materials because new materials may not exactly have the same stress strain characteristics of the material that were used earlier in those old pavements.

If this design procedure is approached for locations where you have very high temperatures very low temperatures what would exactly happen to these materials and as a result what would happen to the performance of the pavement will not be in a position to explain satisfactorily and in a very confident manner. So this is the main problem with empirical pavement designs. The level of confidence with which we can adopt these things cannot be very high. And when we try to transfer this to new conditions we cannot be very sure about what would happen.

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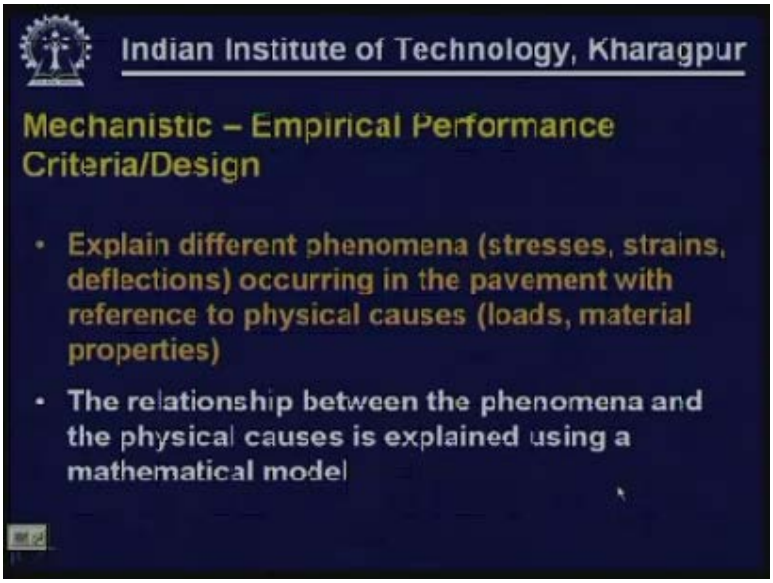

Compared to this we have mechanistic empirical performance criteria and the designs that are based on this mechanistic empirical performance criteria. So we call them as mechanist designs or normally they are called as the mechanistic empirical designs. These try to explain different phenomena or stresses, strains and deflections that occur in pavements. With reference to the physical causes what are the cause related factors? The cause related factors are loads and the material properties so they try to explain why stress is more, why diffraction is more, why strain is more in terms of the material property that we were using, in terms of the loads that are applied. So the relationship between the phenomena, stresses, strains and deflections and the physical causes loads and material properties is explained using a mathematical or theoretical model.

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Normally the mechanistic approach is integrated with empirical approach because empirical approach is nothing but we are observing performance that we are trying to correlate with

some design parameters. But in mechanistic parameter the design parameters would be selected in such a way that they represent the mechanistic behaviour of the pavement materials and pavement as a whole. So the performance is going to be correlated to mechanistic parameters which can explain the mechanistic behaviour of the pavement. So the relationship between the phenomenon and the failure is explained by empirically obtained relationships. Again we have to correlate using some statistical means the performance with the mechanics parameters so that some amount of empiricism is always going to be there because you always have to go to the field observe performance and then correlate that to the design parameters. In this case these are mechanistic parameters, some critical stress and some critical strain or critical deflection that we consider to be important for the performance of the pavement. We are going to correlate these parameters to the pavement performance that has been observed. So that correlation is always there so there is some amount of empiricism that's always going to be there.

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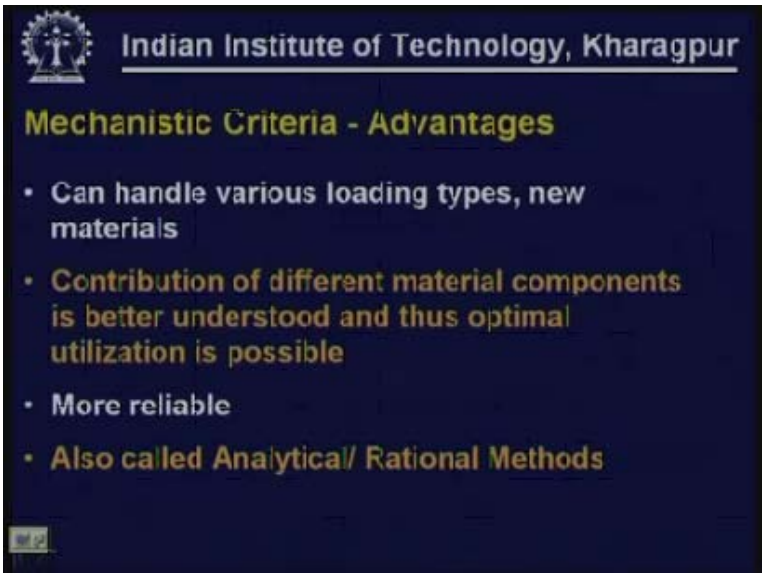

Mechanists criteria: the main advantages is that they can handle various loading types, they can handle new materials. if you vary the materials, if you vary the load, if you are considering a certain mechanistic parameter to be critical, for example, stress at a particular location to be critical then what is the effect of varying material properties, what is the effect of varying load conditions on that particular parameter can be assessed and then that parameter in turn can be correlated to the performance.

Since we already have a parameter which gets affected by all these varying parameters such as material properties, loading conditions, climatic condition or whatever it is they can be taken into account and that critical parameter mechanistic parameter can be computed taking into account all those different loading conditions, different material properties, or any other climatic condition variation that is going to be there so all those parameters can be taken into account in calculating this critical mechanistic parameters that we are using for design.

In this case the contribution of different material components is better understood. What happens if I increase the thickness of base course? What would happen if I decrease the thickness of bituminous surface? My empirical design procedures may not be able to explain because originally all those combinations may not be there, all those materials may not be

there so if cannot explain using an empirical procedure what would happen if I increase the thickness or if I change the material property. But using mechanistic procedure it would be able to satisfactorily explain what would be the result of adopting different materials and analysing different loading conditions.

As a result mechanistic design procedures can be expected to be much more reliable than empirical design procedures. These are also called as analytical or we would rather prefer it to be called as rational. These are more rational than empirical design procedures.

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We have to realize that performance criteria is the heart of the pavement design. Performance criteria is at the centre of any design procedure so this has to be developed properly.

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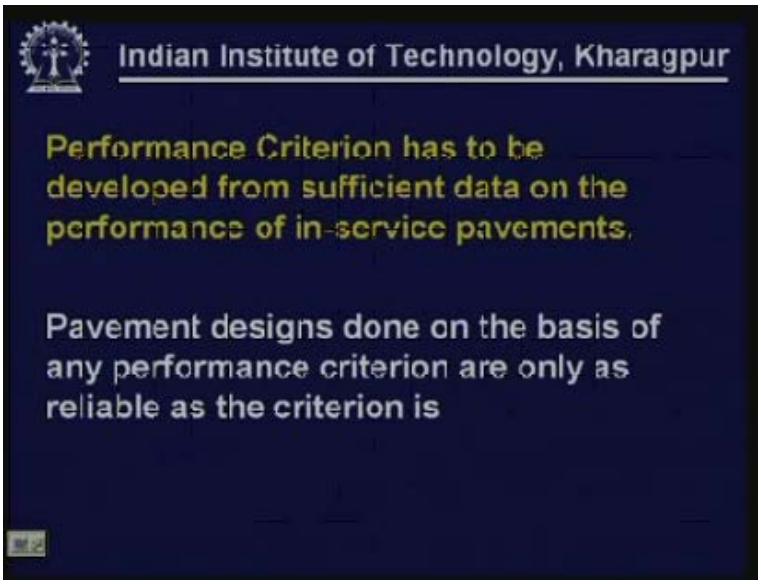

Performance design criteria or performance criteria has to be developed from sufficient data on the performance of in service pavements. Naturally this has to come from observation of a number of pavement sections. And any pavement design that you do on the basis of this performance criteria is only as good as your performance criteria is. If your performance criteria is very good your pavements that you are going to design on that basis is going to be a satisfactory and we can be very confident about the designs.

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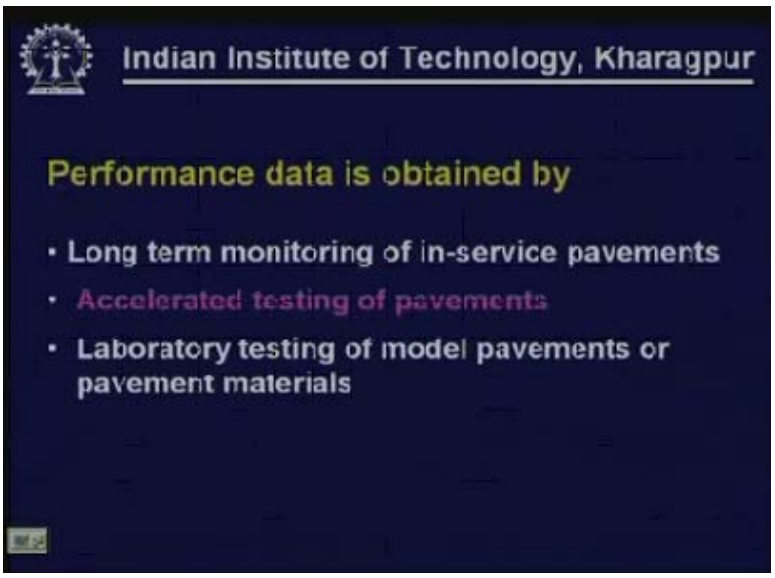

The performance data is usually obtained by long term monitoring of in service pavements. This is the most preferred method if that is possible. In service pavements on highways or any other roads are to be monitored over its complete service life period. The data has to be obtained about the performance of the pavements at regular intervals and then that has to be correlated to. If it is an empirical design procedure it is some simple material properties like the subgrade CBR or if it is a mechanistic one those pavements have to be analyzed and the performance has to be correlated to those mechanist parameters that we select and then the performance criteria have to be developed.

If you cannot go for long term monitoring, if you cannot wait for such long periods, or you have just developed a new pavement material and you cannot construct pavements and wait for fifteen years for it to fail and then collect performance data then you can go for accelerated testing of pavements in accelerated pavement test facilities. Alternately we can test those new materials or new pavement models in the laboratory and then collect information about their behaviour and then on that basis make some adjustment to the laboratory obtained performance as whatever adjustments are required and then you can still develop performance criteria for a pavement design.

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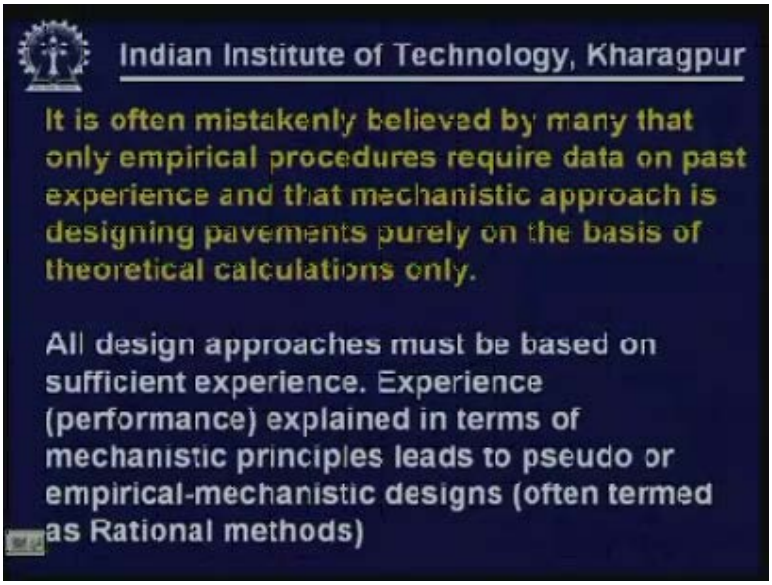

It is often mistakenly believed by many that only empirical procedures require data on past experience and that mechanistic approach is designing pavements purely on some theoretical calculations and then using some calculator or computer we are trying to design pavements. People often try to say I am going to use elastic theory, this theory or that theory, these all purely theoretical there is nothing correlate to practice, it is a mistake. Any design procedure has to be on the basis of observed performance. By mechanistic approach we are only trying to explain the performance in a more rational and more fundamental manner.

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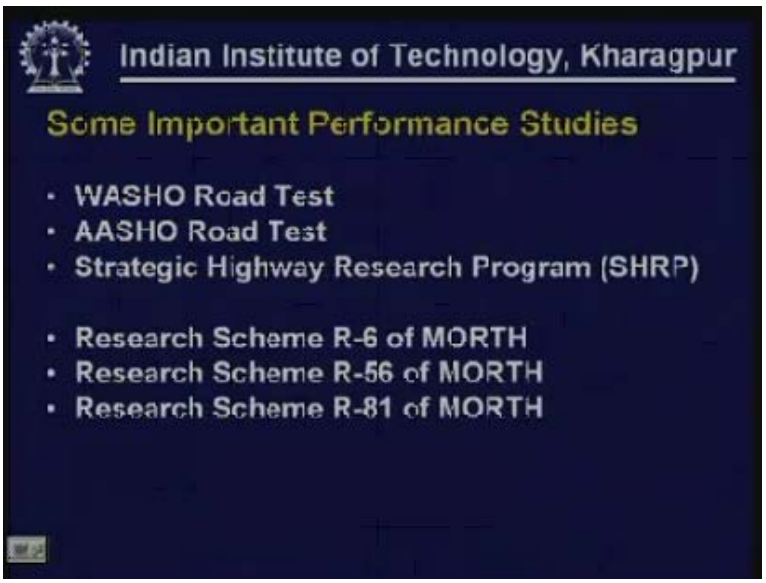

Some of the important performance studies that have been carried out in the past are WASHO road test, AASHO road test, very major and important road test. Most of the present day design concepts and performance concepts have been result of these studies. These were conducted in the 50s and 60s in the United States. A more recent program that the United States had on collecting pavement performance information was the Strategic Highway

Research Program SHRP. In India also we had a number of research programs that were sponsored by the Ministry of Road Transport and Highways MORTH. Important to note among these were R6, R56 and R81 research schemes.

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We can adopt different design strategies. Pavement design is not an exact process. If two different people design pavements for a given situation you can expect that they can come up with different design approaches. There could be several alternative solutions in terms of the type of material, in terms of the type of pavement, in terms of the number of layers that we use and it can be in combination like we can suggest new construction, we can suggest rehabilitation, we can suggest maintenance so there can be various alternative ways of doing a pavement design so there cannot be in exact solution for pavement design.

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Pavements can be designed to serve for long periods without maintenance, this is one approach. That means you have to spend lot of money initially and expect that it doesn't have to be maintained over the next five years, ten years except for very small maintenance. Alternatively you spend less amount of money initially and then expect that every two years, three years or every five years there is going to be some amount of periodical maintenance that is required so you can go for either of these two approaches.

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Design process is basically trade-off between the inconvenience caused to the road user because of frequent maintenance that is required and the high initial cost. If you go for high initial cost the frequent maintenance and the discomfort will be less, if you go for low initial cost intermediate maintenance will have to be done and that will cause more discomfort to the users so it's a trade-off between these two. Such decisions are now-a-days taken on the basis of very rigorous economic analysis carried out on various alternative solutions that you can go for.

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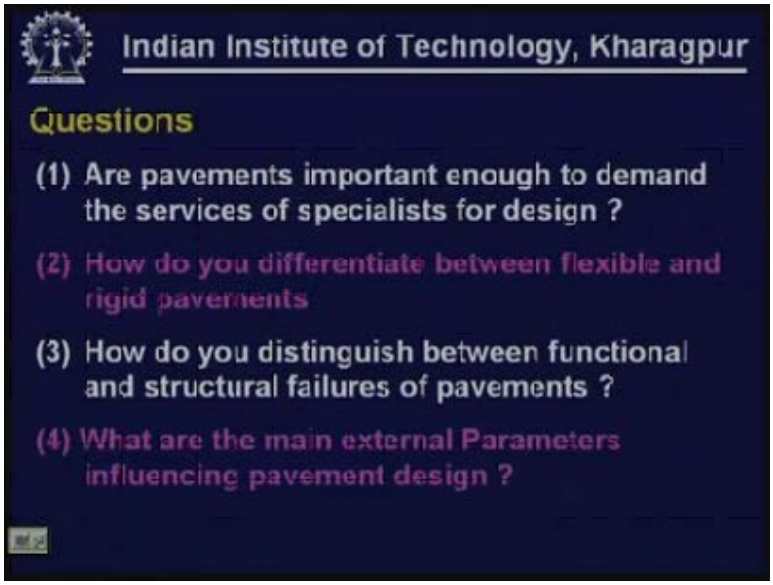

Before you conclude this lesson let us take up a few questions. Answers to these questions will be provided in the next lesson. The first question is;
1) Are pavements important enough to demand the services of specialists for pavement design?
2) How do you differentiate between flexible and rigid pavements?
3) How do you distinguish between functional and structural failures of pavements?
4) What are the main external parameters influencing pavement design?

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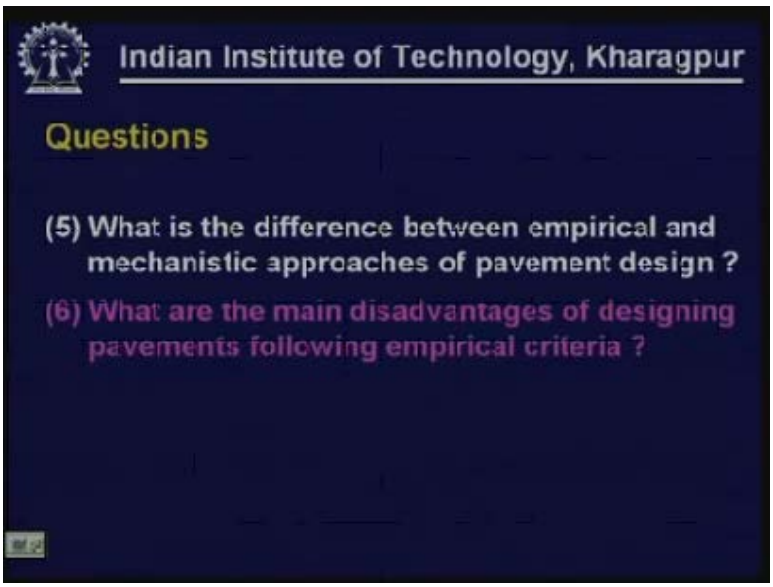

5) What is the difference between empirical and mechanistic approaches of pavement design?
6) What are the main disadvantages of designing pavements following empirical criteria?
Answers to these will be provided in the next class, thank you.

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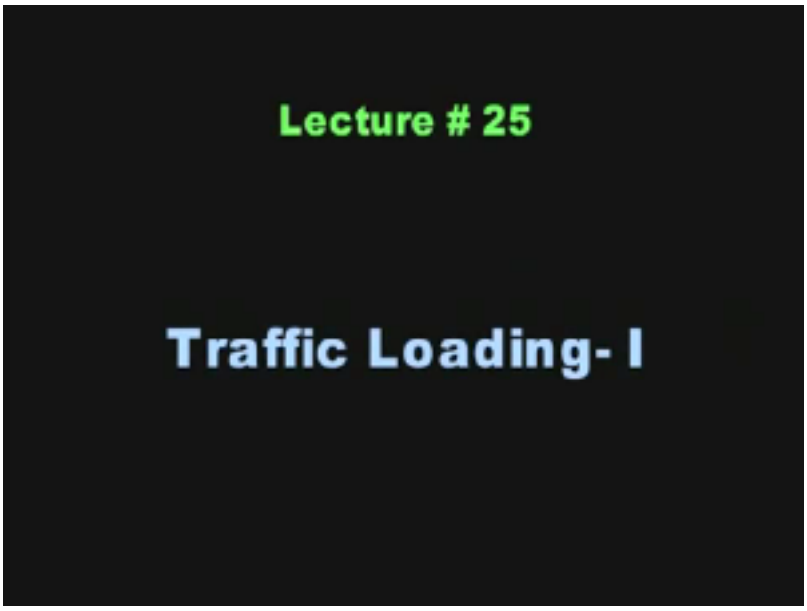

Hello viewers. Welcome to lesson 4.2, Traffic loading- Part 1 of pavement design which is being covered under Module-4.

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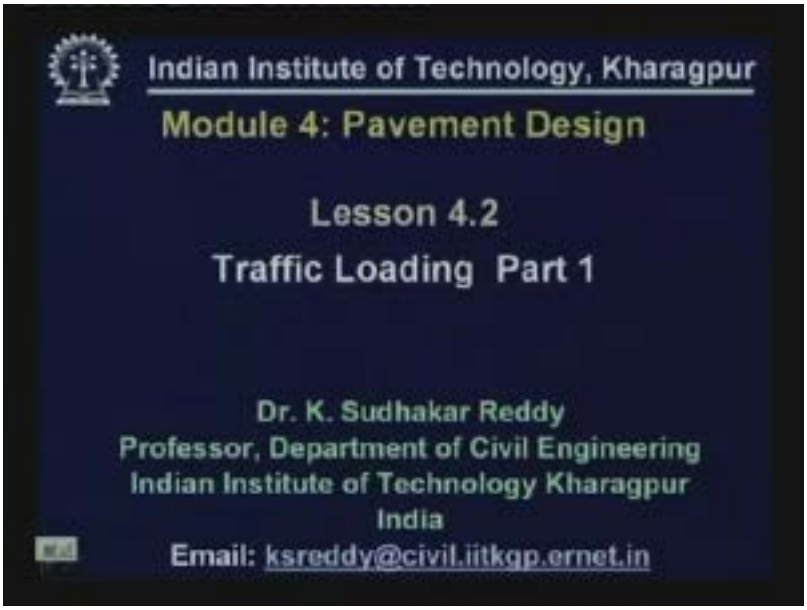

We would be covering traffic loading in two different parts. This lesson pertains to part 1 of traffic loading parameters. In the last class which was on principles of pavement design, we had discussed about three very important external parameters which are external to the pavement that need to be considered for design of pavement. First one was update, second one was traffic parameters and third one was climatic parameters. So, over the next two classes including this, we will be covering various traffic related parameters which is a very important input for pavement design.

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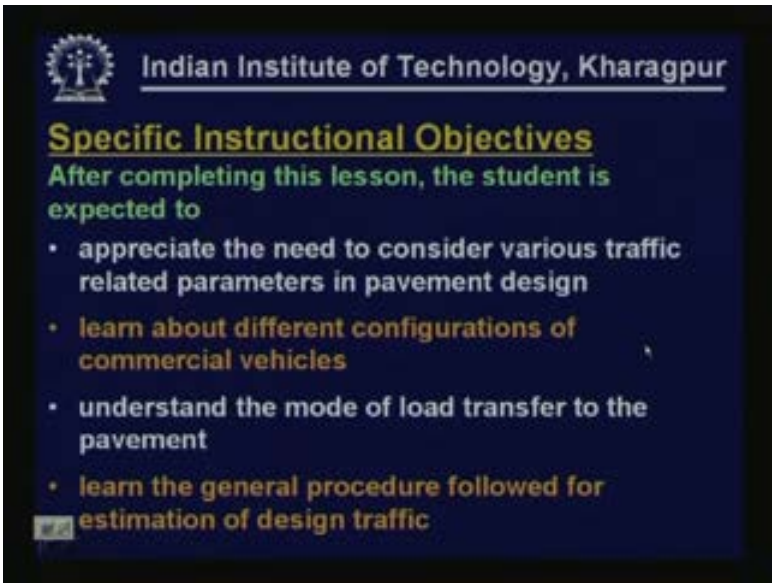

In this lesson we will be covering various aspects of traffic related parameters. So, after having understood this lesson or gone through the contents of this lesson it is expected that the student is able to appreciate the need to consider various traffic related parameters in pavement design; what is the importance of considering different parameters that pertain to

traffic loads in pavement design, and also will be able to learn and understand about the different configurations of commercial vehicles, and understand the mode of load transfer to the pavement, and learn in general about the procedure that is followed for estimation of design traffic for pavement design.

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When we consider traffic loading obviously we are referring to vehicles. We also know that there are different types of vehicles with wide ranging sizes, wide ranging load magnitude and ability to travel at different speeds. We can start with bicycles, two wheelers, passenger cars, we have vans of different sizes and shapes, buses, different types of trucks; single unit trucks, multi unit trucks so we have various combinations, various types of vehicles that ply on roads or highways. We have to consider which one of these vehicles are important for pavement design, which one of these vehicles that we need to consider, which specific parameters need to be considered as inputs for pavement design.

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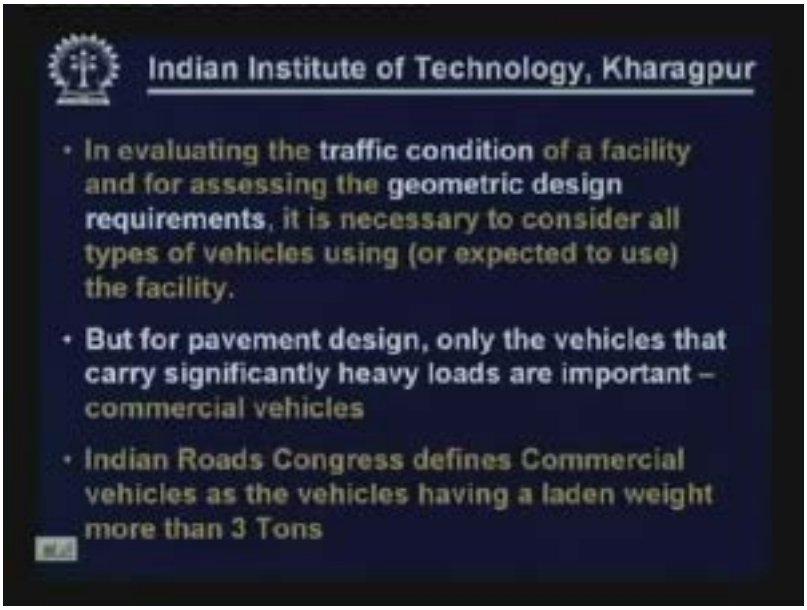

For example, in evaluating the traffic condition, the quality of flow on a given road and for assessing the adequacy of geometric design features so all these aspects you have studied in your earlier lessons. It would be necessary to consider all these vehicles that I have listed in the previous slide; whether it is small or big, whether it carries small load or heavy load so all those things all in terms of permanent deformation […….ing…..58:07] so this is how these two performance criteria or failures are different.

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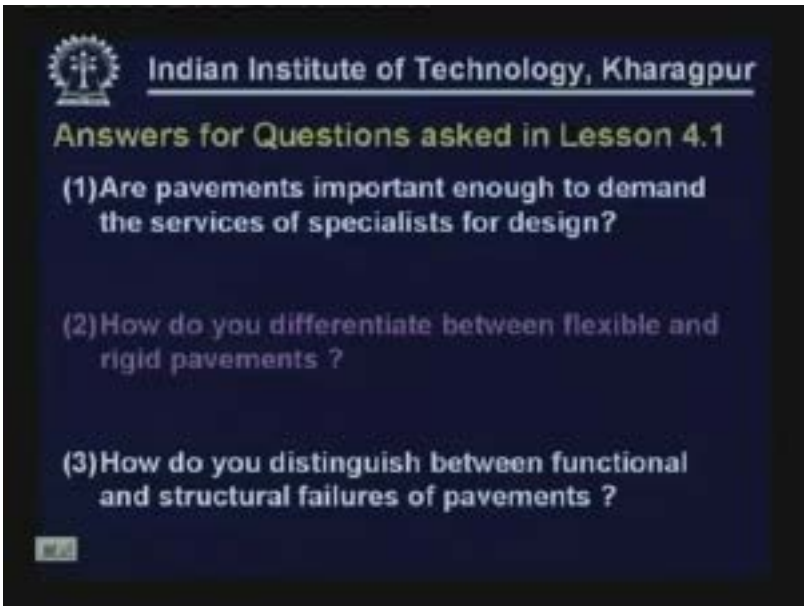

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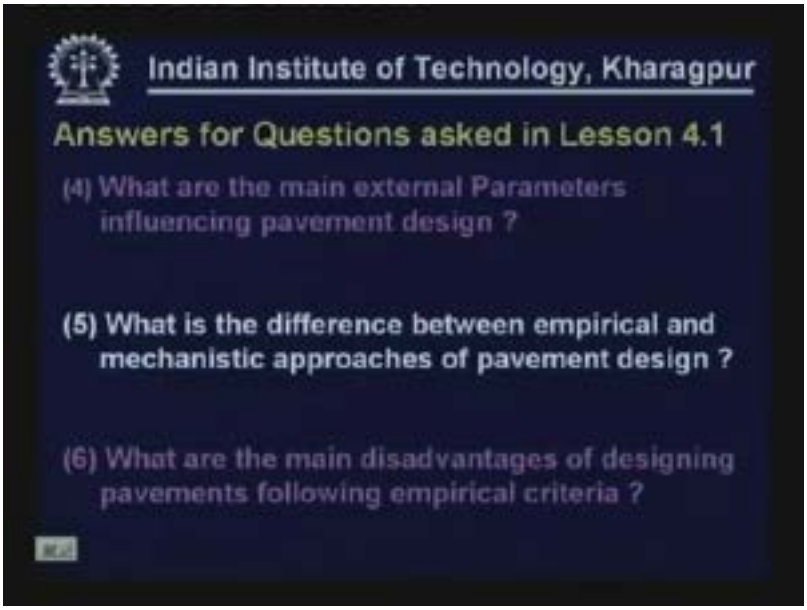

What are the main parameters influencing pavement design this we have discussed just now also. The main external parameters are sub-grade, traffic loads and climatic factors.

What is the difference between empirical and mechanistic approaches of pavement design? Empirical is the design that is developed or the criteria that is developed based on experience and some central parameters whereas in mechanistic approach the experience is correlated to some mechanistic parameters like stress, strain and other critical parameters.

What are the main disadvantages of designing of pavements following empirical criteria? Because this is based on some past experience based on some statistical correlation this cannot be extrapolated to new conditions, new materials, new traffic conditions. It can be done but not with a [……59:08]. So with this we conclude lesson 4.2. Fine, thank you.