Geosynthetics Engineering : In Theory and Practices
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Lecture - 20
Geosynthetics In Pavements

Welcome to lecture number 20, my name is Professor J N Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India, this module's 5, lecture 20, Geosynthetics in Pavement.

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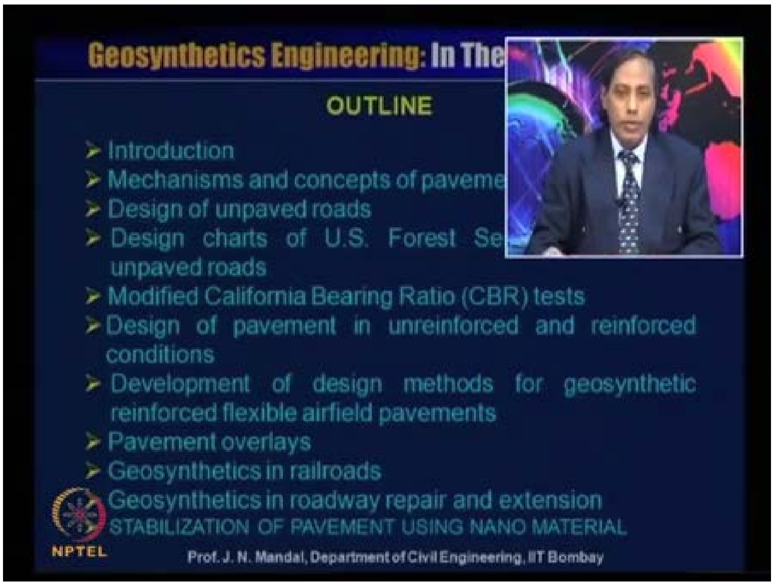

The outline of this course introduction, mechanism and concept of pavement, design of unpaved road, design chart of U S Forest Service USFS for unpaved road, modified California bearing ratio CBR tests. Design of pavement in unreinforced and reinforced condition, development of design methods for geosynthetics reinforced flexible airfield pavement, pavement over lay, geosynthetics in railroad, geosynthetics in roadway repair and extension, and stabilization of pavement using nano materials.

As, you know that basic concept is soil mechanics and the polymer material, you should know what should be the characteristics of the soil as well as what is the characteristics of the polymer material. Then introduction between the soil and the polymer material will ensure, you the different types of the application.

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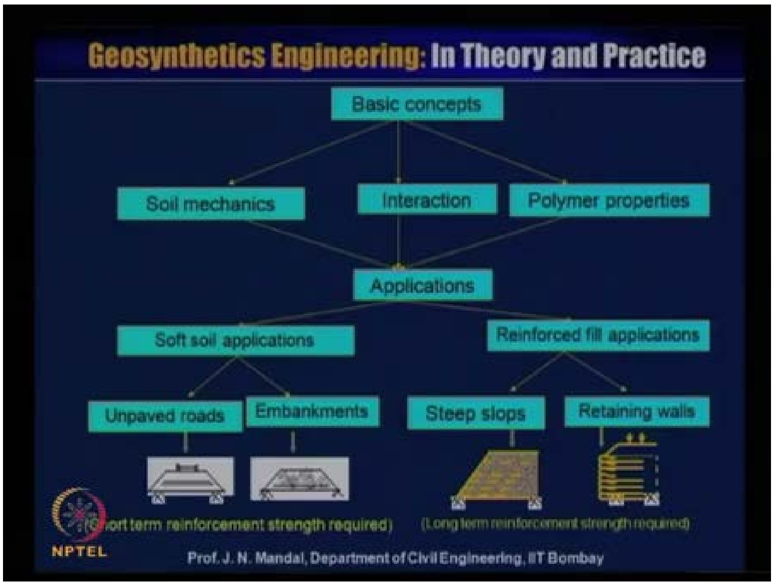

So, it may be soft soil application and then post field application, soft soil application is unpaved road, embankment which is short term reinforcement strength required. And this reinforced fill application is steep slope and retaining wall, and this is for the long term reinforcement strength requirement. So, here that short term reinforcement strength required, and long term reinforcement strength required depending upon the type of the application. In case of the pavement or the temporary infrastructure the short term time is generally 5 to 25 years, if it is a long term it is generally 50 to 100 years, and 70 years for the retaining wall and 100 years for the apartment.

Here, we will concentrate mainly on the a road, so we will discuss that how you can design the road, and this spectacular application of the road that tigarate the acceptance and application, in the earlier 1970's. And we will check that what will be the cost of the aggregate lost, and what will be the cost of the geosynthetics material, and we will be able to tell how much percentage of saving using this geosynthetics material. At the same time it is very important to realize that the geosynthetics must have it is very good tensile modulus or the strength mobilize via the deformation of the soil sub grade material. Road and highway are the backbone of any country in the world for development.

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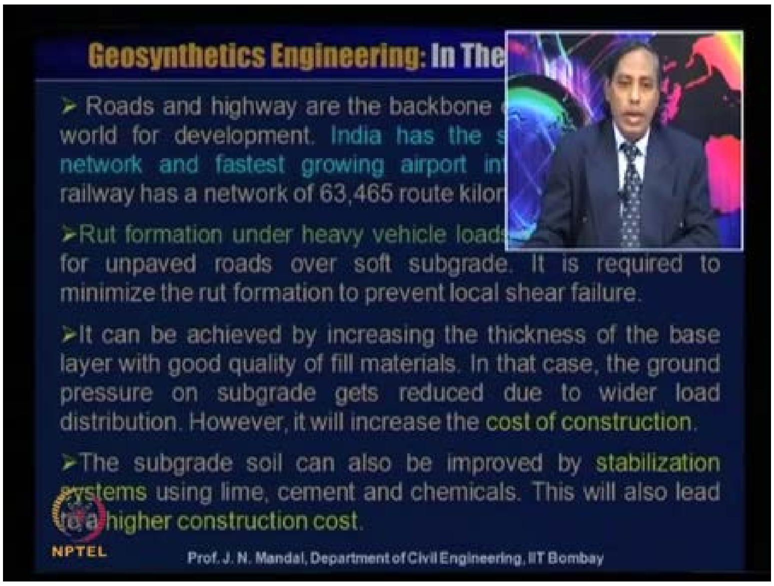

India has the second largest road network and fastest growing airport infrastructure, Indian railway has a network of 63,465 route kilometers, rut formation under heavy vehicle load is a major concern for unpaved road over soft sub grade. It is required to minimize the rut formation to prevent the local shear failure, it can be achieved by increasing the thickness of the base layer with good quality of fill material. In that case the ground pressure on sub grade gets reduced due to wider load distribution; however, it will increase the cost of construction. The sub grade soil can also be improved by stabilization system using lime, cement, and chemical, this will also lead to a higher construction cost.

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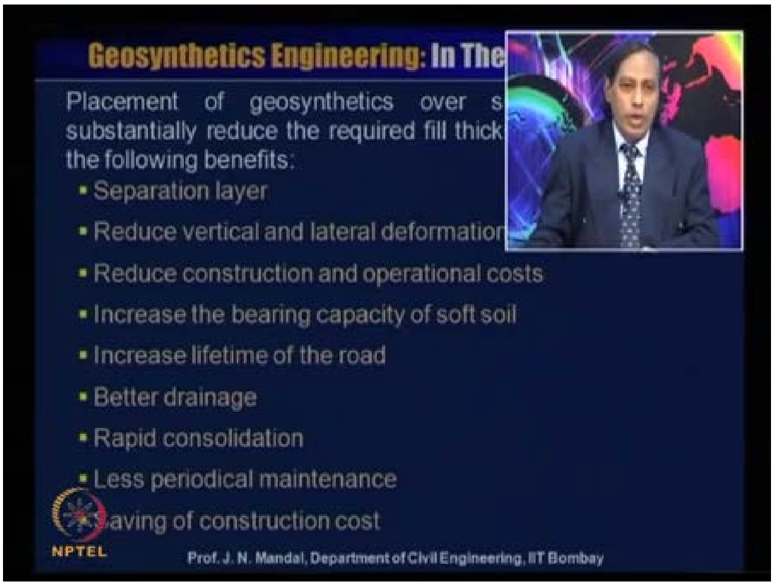

So, placement of geosynthetics over sub grade soil can substantially reduce the required fill thickness, it can provide the following benefit, it act as a separation layer, reduce the vertical and lateral deformation, reduce construction and operational cost. Increase the bearing capacity of soft soil, increase lifetime of the road, better drainage, rapid consolidation, less periodical maintenance, and saving of the construction cost.

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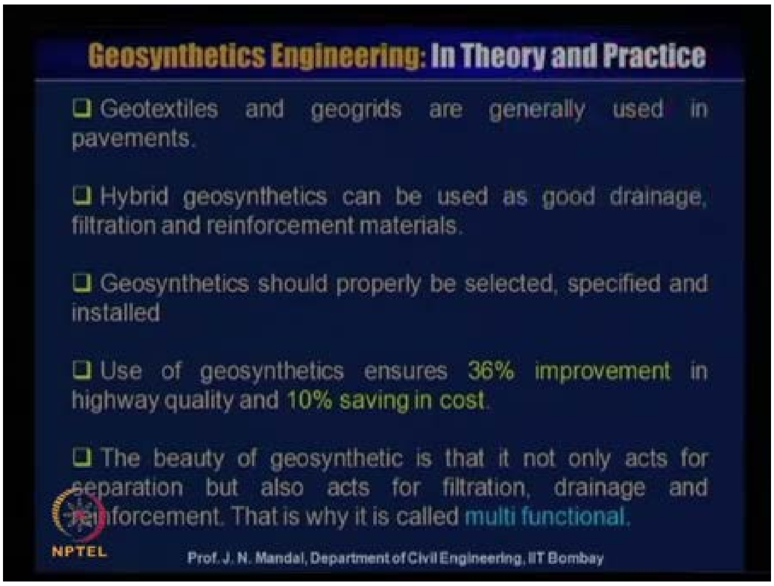

Generally geotextile and geogrid and combination of geotextile and geogrid are used in the pavement, hybrid geosynthetics can be used as a good drainage filtration and reinforcement material. So, it act as a both reinforcement as well as drainage and the filtration, because it is a combination of geogrid and other woven and non woven geotextile material.

So, geogrid can take care as a reinforcement function, where as the woven and non woven geotextile material can take care as a filtration and drainage function. Geosynthetics should properly be selected specified and installed, use of geosynthetics ensure 36 percent improvement in highway quality, and 10 percent saving in cost, the beauty of geosynthetics is that it not only act for separation, but also act for the filtration drainage and reinforcement. That is why it is called multi functional.

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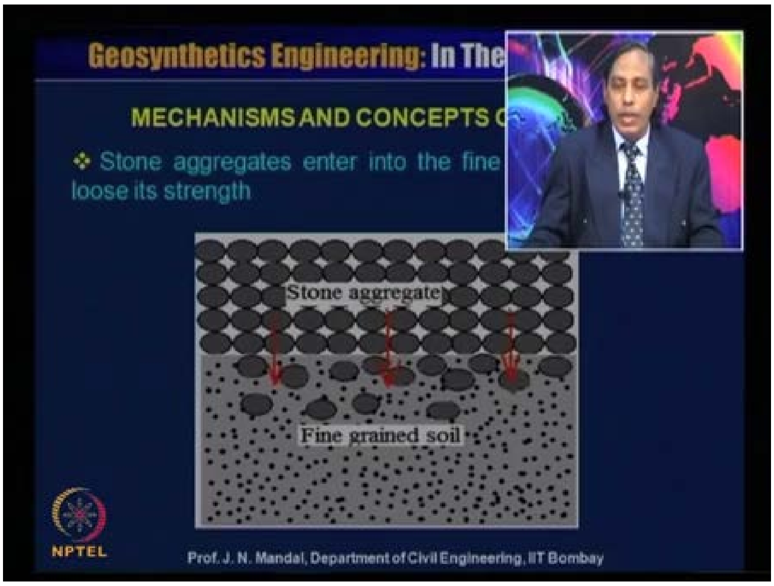

Now, in general that what are the benefit you can obtain in terms of the functional concept, for example that it separate the courser material and the finer material; that means, is reduced the intensity of the stress on the sub grade. And also pavement stone penetrating into the sub grade, so it can reduce, so it act as a separation, so this is the benefit in terms of the functional aspect.

Then also as a reinforcement as well as the filtration aspect that it can prevent the sub grade fine, from the pumping or migrating up into the base course. So, that here the benefit in terms of the separation and the filtration, also it comes the benefit in terms of the filtration. suppose, it can prevent the contamination of the base material of the open graded from the drainage to be considerate into the design, it also act as a separation and reinforcement function and it can reduce the depth of the excavation, you do not require the too much of the excavation of the soil.

So, it can reduce, and you can remove only the unsuitable material from the site, and then you can place the geosynthetics material, it can also reduce the thickness of the aggregate. So, thickness of the aggregate material also can be reduced drastically, and reduce the differential settlement of the road which will tear geosynthetic material act as a reinforcement, and also it can reduce the maintenance and the extend the life of the pavement, so these are the some of the benefit in terms of the functional aspect.

Now, let us look that what should the mechanism and concept of pavement, now here you can see that this is a fine grained material, this is the stone aggregate, so this stone aggregate enter into the fine sub grade soil and loose it is strength. As, you know that stone is very good material for the improvement of the bearing capacity, now this stone aggregate get lost into the finer grain soil, so what geosynthetics can help you.

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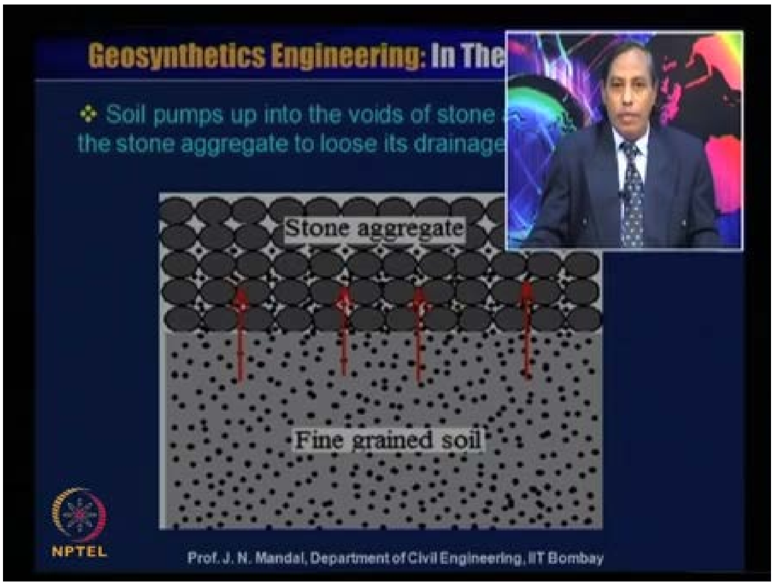

Now, sometimes you can see there is a excess pro order pressure in the fine grain soil, and soil pump into the void of the stone aggregate, causing the stone aggregate to loose it is drainage capacity. And at the same time you know that stone is very good drainage material, and this also get lost, and it clog when the fine material enter into the wide of the good quality of the aggregate.

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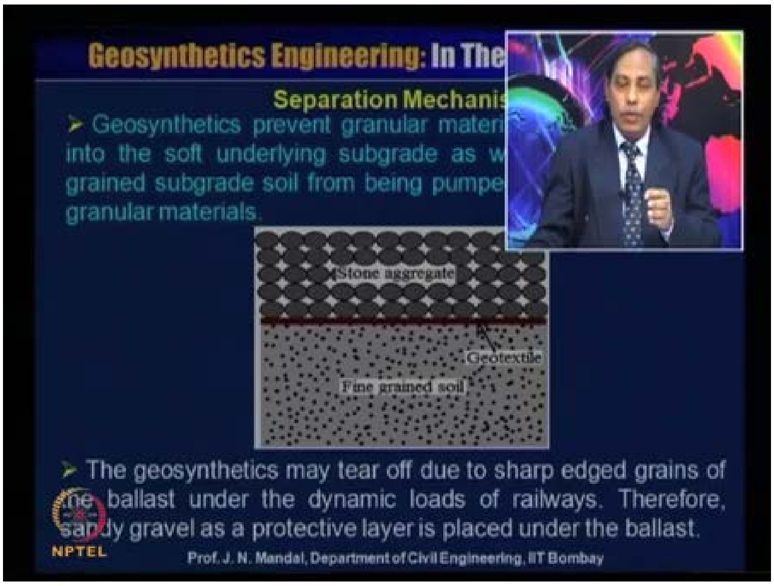

Now, what is role of the geosynthetics material, now if you can introduce a layer of geosynthetics material in between the finer grain soil and the stone aggregate, so here this geosynthetics material act as a separation. So, geosynthetic prevent the granular material from penetrating into the soft underlying sub grade as well as prevent fine grained sub grade soil, from being pumped or migrated up into the permeable granular material. So, geosynthetic may tear off due to the sharp edged grain of the ballast under the dynamic load of railway, therefore sandy gravel as a protective layer is placed under the ballast, where there is a dynamic load, so it will act as a cushion.

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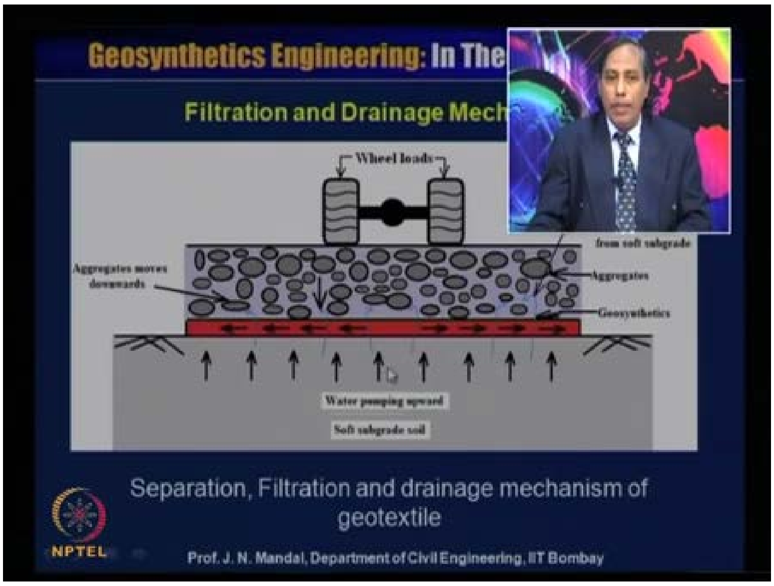

Now, in this slide show that how the geosynthetics material, act as a filtration, act as a drainage, and also act as a reinforcement, so here is the aggregate, that is aggregate try to move downward into the soft sub grade soil. And the water from the soft sub grade soil pumping upward or the water can migrate it this upward into the void of the stone aggregate, due to the fill load.

Now, water also at the same time drained it out from the sub grade soil, so when you place the geosynthetics material, so when the water may move up from fine grains to the courser material or any rain water, which comes to the coarse aggregate can enter into the soft sub grade material. Where, this geosynthetic material act as a filtration, also the water move from fine grains to the coarser grain, or coarser grain to the finer grain, and water can pass along the plane of the geosynthetics material, so here this geosynthetics material act as a drainage.

So, you can see that geosynthetics material act as a filtration, and at the same time geosynthetics material act as a drainage, and also this geosynthetics material will separate the coarser and the finer material, and that is why geosynthetics material act as a separation. Also, due to the load there is a deformation of the geosynthetics material, and then also geosynthetics material will act as a reinforcement, so all these function will do at a time and that is called the multi function.

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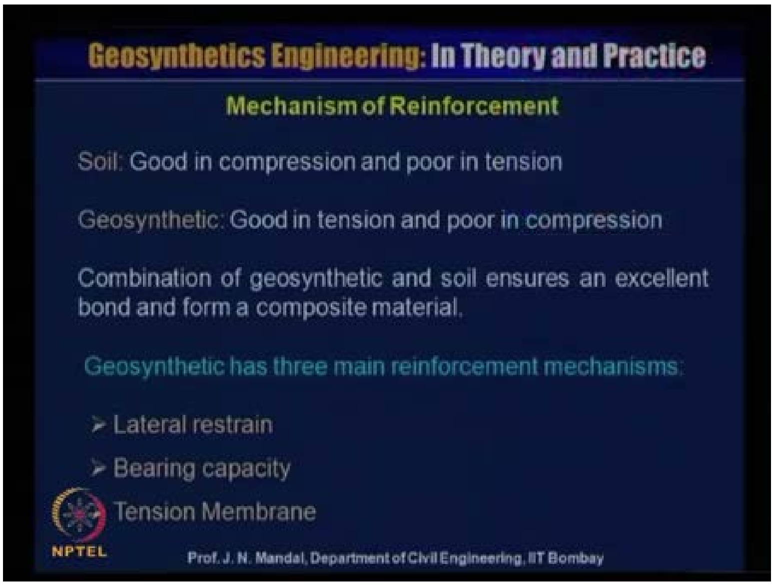

Now, mechanism of reinforcement as you know soil good in compression and poor in tension, geosynthetic good in tension, but poor in compression, so combination of geosynthetics and soil ensure, an excellent bond and form a composite material. Now, when you will design the geosynthetics reinforced pavement, and it is based on the 3 main reinforcement mechanism, this is very important to us. What are those 3 main reinforcement mechanism, the 1 mechanism is the lateral restrain, second is bearing capacity, and third is the tension membrane.

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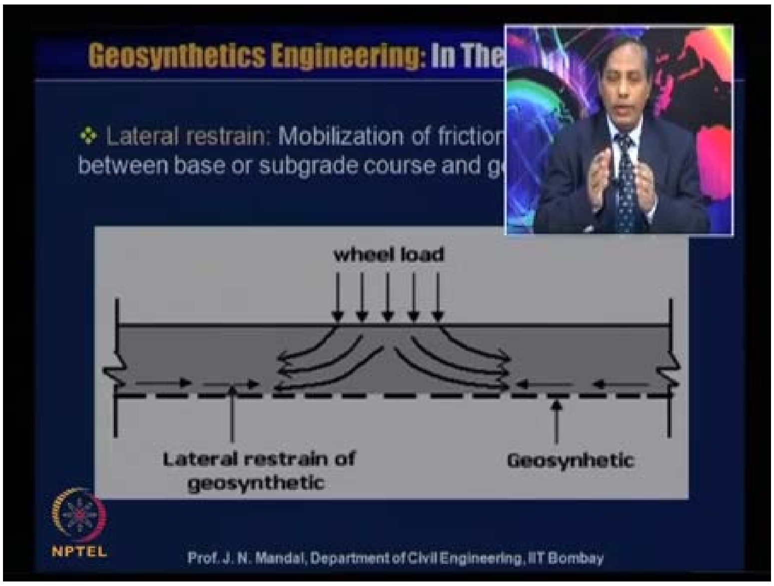

Now, what is lateral restrain, you can see here this is the dot, dot line is the geosynthetics material, this is geosynthetic material, so you can say lateral restrain that when you apply the load, then aggregate will try to move outward. So, there will be a mobilization of friction, and or interlocking between the base or sub grade course and the geosynthetics material.

So, aggregate will push outward and geosynthetic material, which combide the lateral restrain, so that is why this is the lateral restrain of the geosynthetics material in shown in arrow here, similarly on the right hand side. So, due to the wheel load there is a mobilization of friction, or if it is a geogrid material there will be a interlocking or bonding between the base course and the sub grade course and the geosynthetics material, so that is the why that lateral restrain mechanism is important to us.

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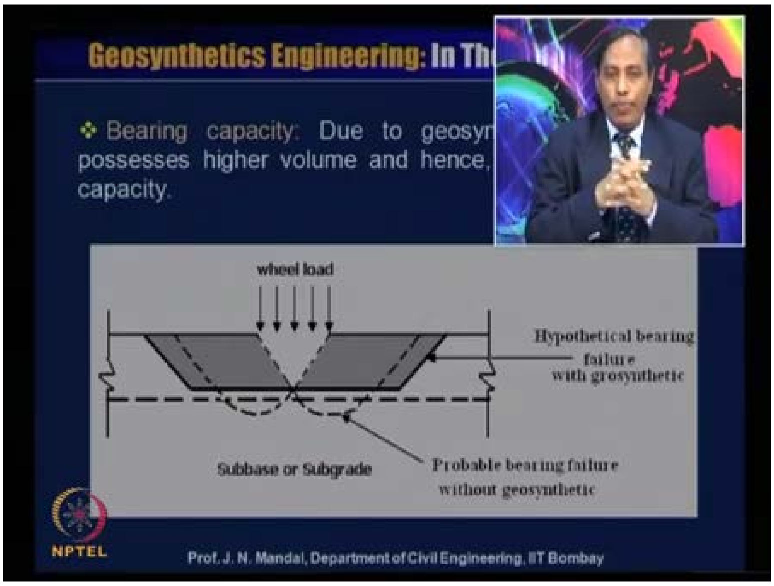

Next bearing capacity, so you can see this is the wheel load, and this is the geosynthetics material is placed, due to geosynthetics the failure zone wazsesth higher volume and hence increase the bearing capacity. You see in the conventional or the probable bearing failure without geosynthetics, you know it is passing like this, this is the probable bearing failure without geosynthetics like this, this dot line.

On the other hand, if you provide with the geosynthetics material, then this is the hypothetical bearing failure with geosynthetics, you can see it is like this and it is like this. That means, there is a increase in the bearing capacity, because geosynthetics failure zone passes higher volume, it passes higher volume with respect to probable bearing failure without geosynthetics material. And that is the reason that why the bearing capacity has been substantially improved due to the presency of geosynthetics material, so this is the second mechanism that how the geosynthetics material can improve for bearing capacity.

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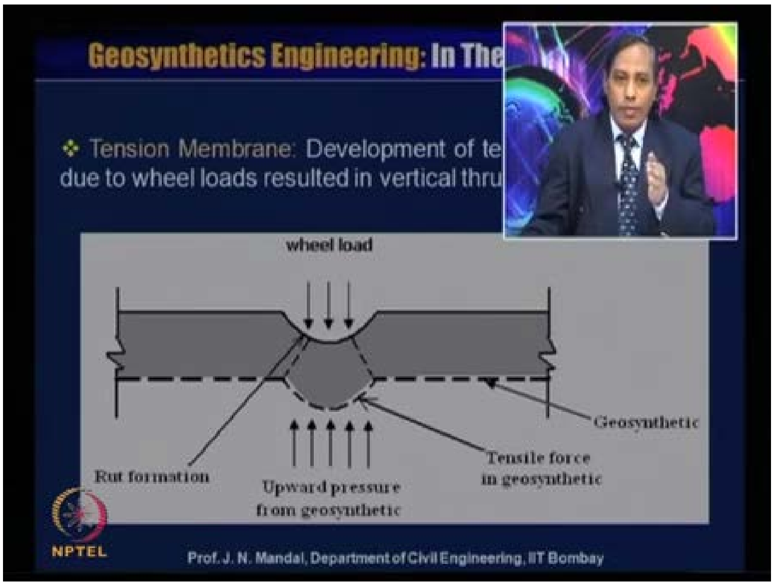

Now, third tension membrane, so you can see if we apply the wheel load, and then there will be the development of tension, this is the geosynthetics material you apply wheel load there is a development of tension. Test is the tension is T, in the geosynthetics material due to wheel load, resulted in a vertical thrust there is a upward pressure from the geosynthetics material.

So, when there is no reinforcement the entire thing may go down, on the other hand if we can provide with the one layer of geosynthetics material, so there will be the upward pressure from the geosynthetics. And there will be a development of tension both the side tension, and at the same time there is a formation of rut, so rut will pump, so we have to select that how we can minimize the rut.

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So, these are the three basic mechanism of the geosynthetics for the unpaved road, I mention that there is a lateral restrain, there is a improvement of the bearing capacity, and also there is a development of tension membrane. That means, tensile strength of the geosynthetics material is very important to us, what should be the modulus of the geosynthetics material, that is very important to us. Now, you can see some figure that what are the kind of the problem in the unpaved road, you can see is very typical, this is a formation of the rut, very difficult to move any vehicle you can see water also is stagnant very difficult.

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To move can see some unpaved road, and if you do not provide with the geosynthetics material, then you cannot control the car.

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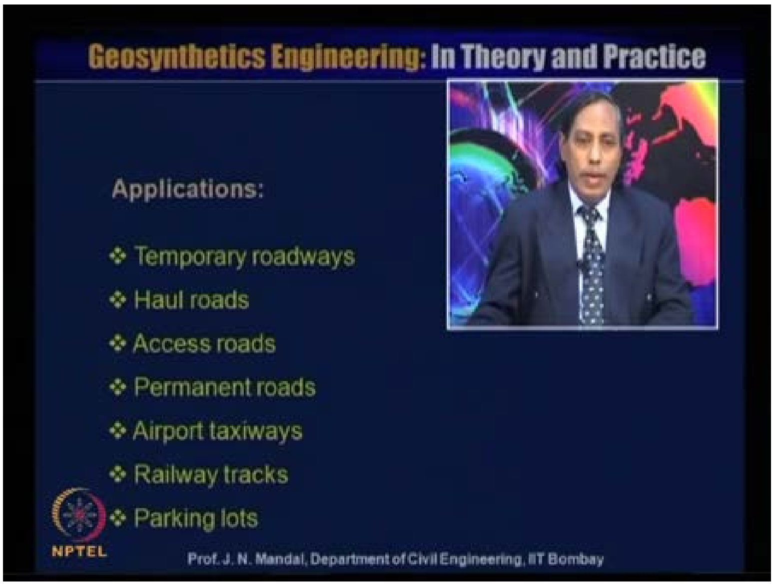

So, there are various application, it may be for temporary road way, haul road, access road permanent, road airport taxi way, railway track, parking lot etcetera.

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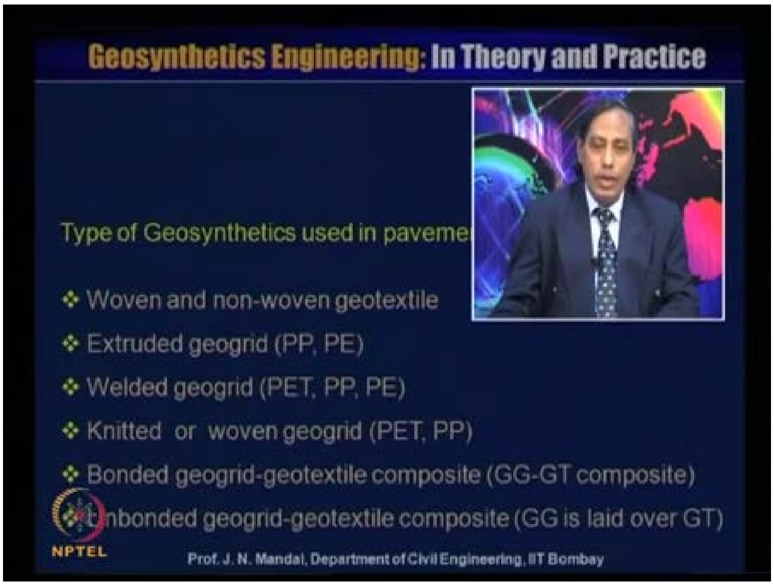

So, what type of geosynthetics material used in the pavement, it may be woven and non woven geotextile material, extruded geogrid poly propylene, poly ethylene, welded geogrid, polyester propylene, poly ethylene. Knitted or woven geogrid, polyester poly propylene, bonded geogrid geotextile composite, that mean geogrid and geotextile as a composite material, where geogrid will act as a reinforcement. And geotextile will act as a filtration or drainage unbounded geogrid geotextile composite, that is geogrid is laid over geotextile material.

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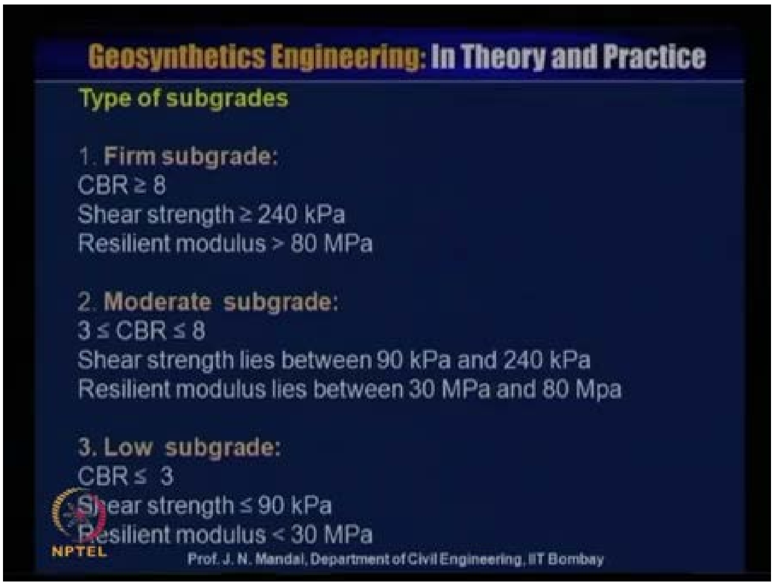

Now, what will be the type of the sub grade, it may be the firm sub grade if the California bearing ratio or CBR greater than equal to 8, and shear strength value greater than equal to 240 Kilopascal, and resilient modulus is greater than 80 Megapascal mpa. Number 2 if it is a moderate sub grade; that means, when the CBR is greater than equal to 3, but less than equal to 8. Then shear strength lies between 910 kilopascal, and 240 kilopascal, and resilient modulus lies between 30 megapascal and 80 mega pascal.

Number 3 low subgrade, if CBR less than equal to 3, then shear strength less than equal to 90 kilopascal, and resilient modulus less than 30 megapascal, these are the some kind of the sub grade condition. So, sub grade condition for unpaved road generally should lie within this range, it should not be some severe value much, much higher then may be geosynthetics material has no role, but if it is a very soft soil. You know where severe value less than equal to 3 or severe value greater than equal to 3 or less than equal to 8 or certain extent severe value greater than equal to 8 is reasonable, and then you can apply this geosynthetics material for improvement.

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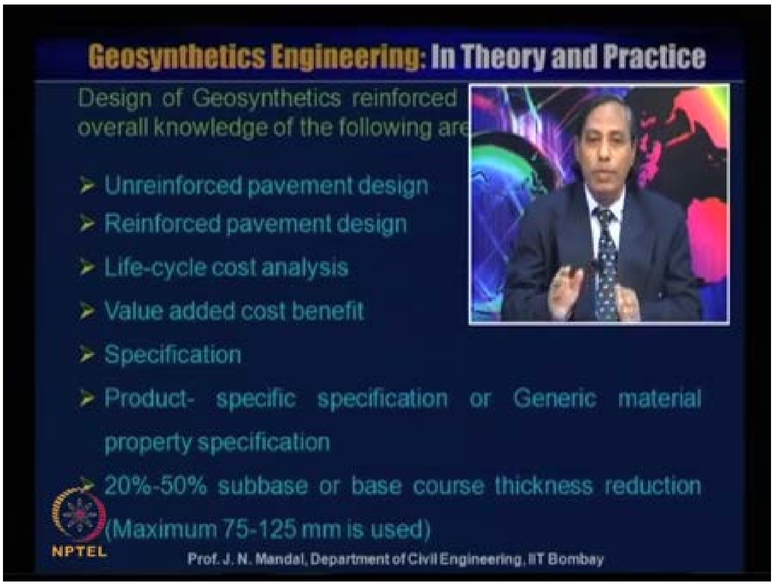

Now, design of geosynthetics reinforce pavement require an overall knowledge of the following area, unreinforced pavement design, reinforced pavement design, life cycle cost analysis, value added cost benefit, specification. Product specific specification or generic material property specification, 20 to 50 percent sub base or base course thickness reduction, maximum 75 to 125 millimeter is used.

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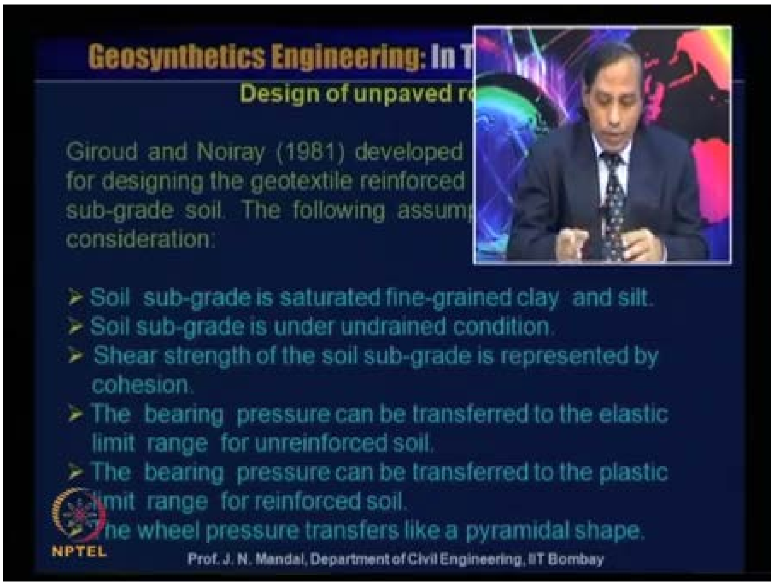

Design of unpaved road, Giroud and Noiray, 1981 developed an analytical method for designing the geotextile reinforced unpaved road on soft sub grade soil, and he assumed the following step that is soil sub grade is saturated fine grained clay and silt. So, it is a saturated soil, the tow is equal to the sea shear, strength is equal to the coison value, and soil sub grade is under undrained condition.

So, no drain condition, shear strength of the soil sub grade is represented by the cohesion only, no angle of internal friction the bearing pressure can be transferred to the elastic limit range for unreinforced soil. And the bearing pressure can be transferred to the plastic limit range for reinforced soil, and the wheel pressure transfer like a pyramidal shape, so before that I just wanted to show that, what is the happening if it is a unpaved road and is defined without geosynthetics material.

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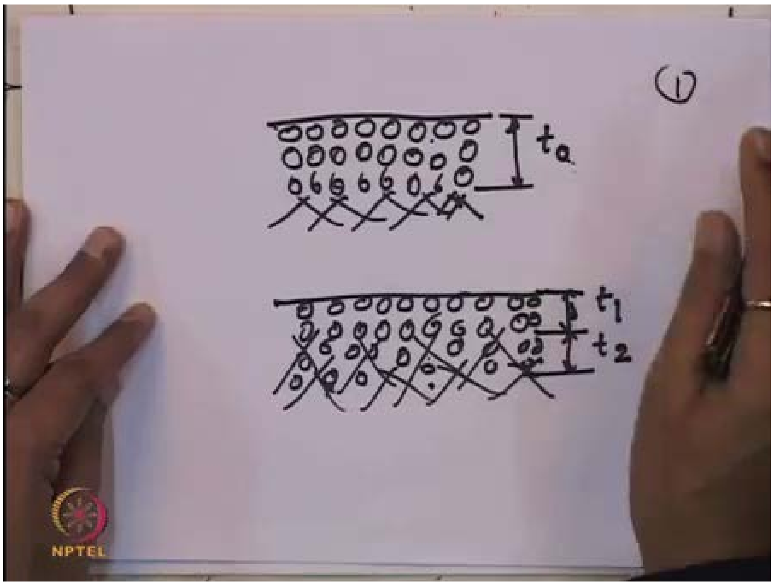

So, if this is the aggregate and thickness is equal to t 0, this is unpaved road as it is designed without any geosynthetics material, let us say this thickness is t 0, and now some same road when after a few week or the month. So, what will happen, the some parts of the aggregate penetrated into the sub grade soil, so you can see here some aggregate is penetrated into the sub grade soil. So, this thickness if I say t 1, and this thickness if i say t 2, so this t 1 is the effective useful base course thickness, it must less than this t 0, that is required design thickness. So, this is the effective useful base course, t 1 is the effective useful base course thickness is must less than the t 0, that you call design thickness.

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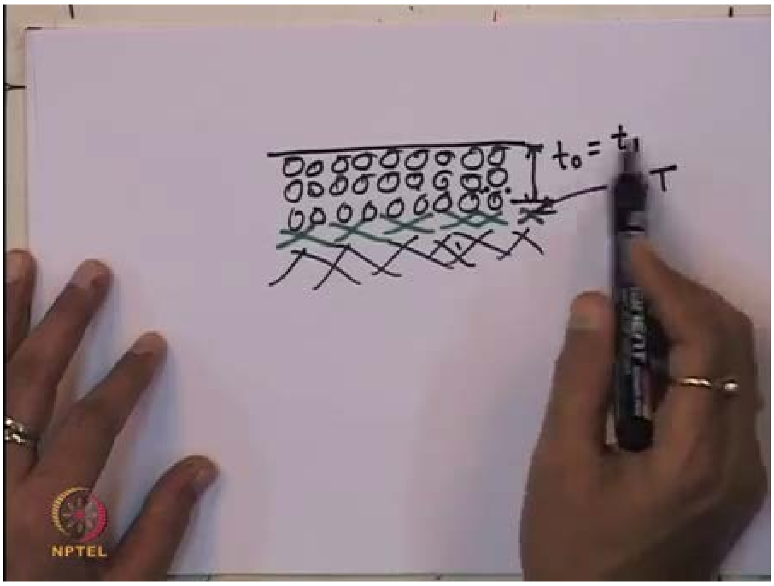

So, now, if you provide a reinforcement in between, so if you place a one layer of the reinforcement or geosynthetics material here, so this is geotextile, this is geotextile material you can say geotextile material. And then this thickness is t 0 is equal to t 1; that means, aggregate intact even after the considerable use, because the pressure of the geotextile then t 1 is equal to t of g.

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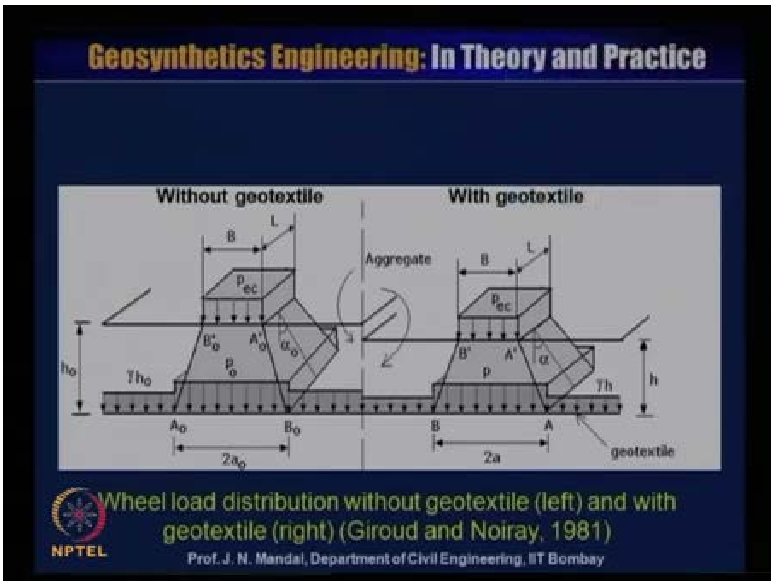

So, this is the wheel load distribution without geotextile that is on the left, and with geotextile on the right, this is reported by Giroud and Noiray in 1981. Now, here you consider this is a as a solid foundation POD of the geotainicl engineering can be utilized, now this is the geomatic model is given by giroud and Noiray this is without geotextile material. Now, this entire wheel load of the pressure P ec on the area that is B, and the L, so tire wheel load and the pressure on the area B is the width of the tire, L is equal to length of the tire.

So, B into L area which dissipated through the thickness of the aggregate base without geosynthetics material at an angle alpha 0, so this is pyramidal geometric shape due to the load ready. So, due to the load spreading you can see how it is a pyramidal geometric shape, formation of pyramidal geometrical shape and in unreinforced case it is making at an angle of alpha 0.

So, here h 0 is the thickness of the base course without geotextile material, and stress is p 0, and this height is h 0, gamma is the unit weight of the aggregate, so this will be gamma into h 0. So, you can see that how the stress has been distributed, here it is A 0 dash to B 0 dash, then after the application of the load and it is a 0 to B 0, and this is 2 of A 0, now this is the pyramidal geometric shape when there is no geosynthetics material.

Now, right hand side when the geosynthetics material has been introduced, now same that tire wheel load of pressure P ec on the area B into L area which is dissipated through the aggregate base course with the geosynthetics material. And it is making at an angle of alpha, and here h is equal to the thickness of the aggregate base course, here it is h 0 unreinforced case, and here it is h in the reinforcement, and gamma is the unit weight of the aggregate, so the this will be gamma into h.

So, in case of with geotextile, this is A dash into B dash, and this is A into B, and this distance is equal to 2 into A, so this is the basic concept and mechanism which is given by the Giroud and Noiray. And based on this concept and mechanism, it has developed and cohesion and formed that equation, which will show how you can make the design chart for without and with geosynthetics material.

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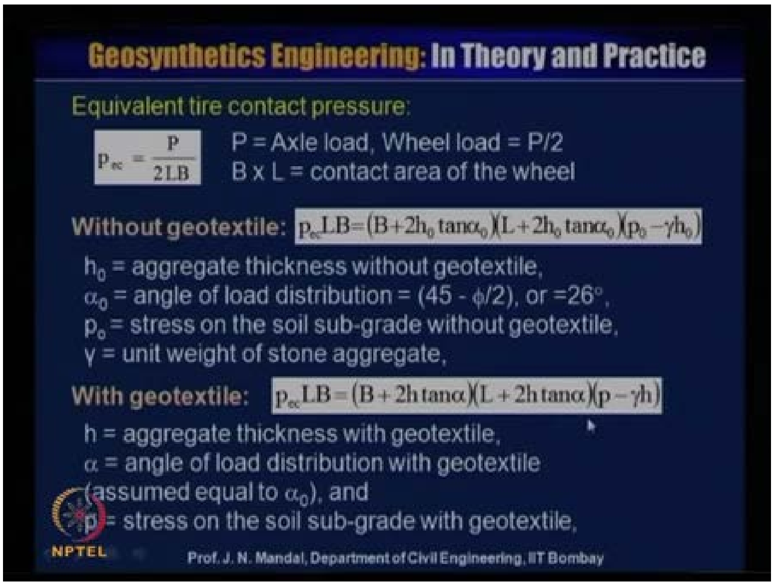

Now, equivalent tire contact pressure, that is P ec, P ec is equal to P divided by 2 into L B, P is the axle load, so wheel load will be P by 2, so that is why the equivalent tire contact pressure P ec is equal to P by 2 into L B. As, I say B into L is the contact area of the wheel, this is width of the tire, and this is length of the tire, so this contact area of the wheel will be B into L, so equivalent tire contact pressure P ec is equal to P by 2 L B.

Now, without geotextile you can write P ec into L into B is equal to B plus twice h 0 tan alpha 0 L plus twice h 0 tan alpha 0 P 0 minus gamma into h 0, as I say h 0 is equal to aggregate thickness without geosynthetics. And alpha 0 is the angle of load distribution that is 45 degree minus pi by 2 or 26 degree, and this P 0 is the stress on the soil sub grade without geotextile, and gamma is the unit weight of the aggregate.

So, this is the B, I am explaining you P ec into L B; ((Refer Slide Time: 41:06))that means, P ec into this area B into L will be equal to B plus twice h 0 tan alpha 0, this is B, and this point, you can see this is the h 0, from here to here h 0 this angle is alpha 0. So, this will be h 0 tan alpha 0, similarly this side h 0 tan alpha 0, so it will be the 2 h 0 tan alpha 0 so; that means, this B plus 2 h 0 tan alpha 0, similarly L plus 2 h 0 tan alpha 0.

You can see this side is the L, so this will be l plus 2 h 0 tan alpha 0, that is why l plus 2 h 0 tan alpha 0, and here is this is the P 0, the stress P 0, so P 0 minus gamma of h 0. So, then this will be P 0 minus gamma h 0; that means, P into L B after the dissipate, then it will be equal to b plus twice h 0 tan alpha 0 l plus twice h 0 tan alpha 0 into P 0 minus gamma h 0, this is P 0, this is gamma h 0, so this is without geosynthetics material, so you can obtain this equation.

Now, with geotextile material this equation will be on the right hand side P ec into B into L, that is area will be equal to similarly this angle is alpha, so this area will be B plus twice h tan alpha into this side is the L, L plus twice h tan alpha. B plus twice h tan alpha into L plus twice h tan alpha and this is P, and this is gamma h, that is P minus gamma h, so this will be equal to P minus gamma h.

So, with geotextile material P ec into L B is equal to B plus twice h tan alpha L plus twice h tan alpha P minus gamma h, you know here h is equal to aggregate thickness with geotextile material. And alpha is the angle of load distribution with geotextile material, and assumed to be equal to alpha of 0, and P is the stress on the soil sub grade with geotextile, here P 0 is the stress on the soil sub grade without geotextile.

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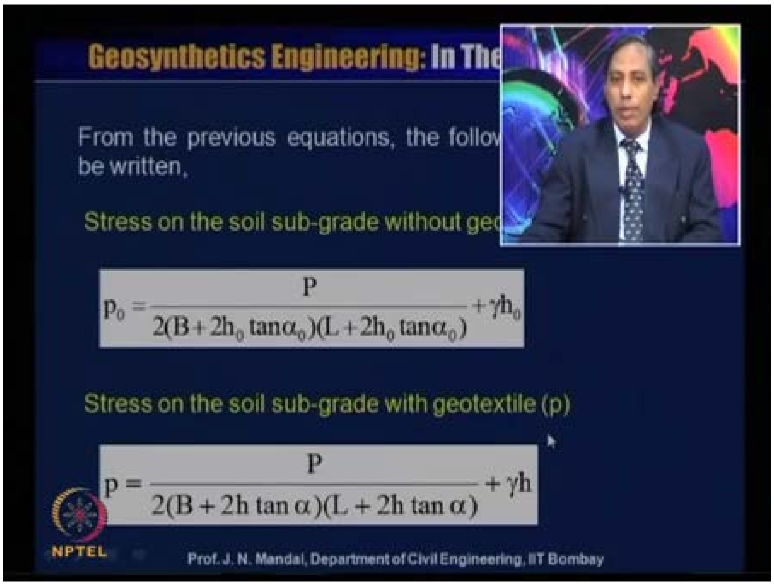

Now, from the previous equation, so we can write the following equation that what should be the stress on the soil sub grade without geotextile, and what should be the stress on the soil sub grade with geotextile. Stress on the soil sub grade without geotextile is P 0, so P 0 will be equal to P divided by 2 into B plus twice h 0 into tan alpha 0 into L plus twice h 0 tan alpha 0 plus gamma h 0.

So, you can this and from this you have to determine what should be the P 0, so this P 0 because you know this is P ec is equal to P by 2 L B, so if you substitute this here P by 2 L B, so L B will be the cancel, so this will be the P by 2. So, this you can write from here, that P 0 will be equal to P divided by 2 B plus 2 h 0 tan alpha 0 into L plus 2 h 0 tan alpha 0 plus gamma into h 0, this is gamma into h 0.

You are substituting this P ec here P by L B you know, then from here you are calculating P h 0, on that side then it will be the gamma of h 0, so this you are having the stress on the soil sub grade without geotextile material. Now, similarly stress on the soil sub grade with geotextile is P, so P will be equal to P capital divided by 2 into B plus twice h tan alpha L plus twice h tan alpha into gamma of h, so from this also you can determine. So, we know what will be the stress on the sub grade soil with and without geosynthetics.

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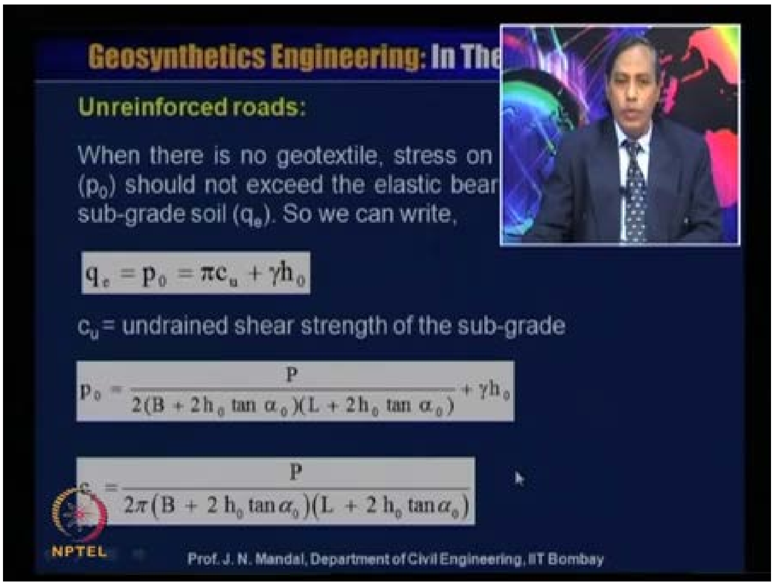

Now, unreinforced road, when there is no geotextile material stress on the sub grade soil, P 0 should not exceed the elastic bearing capacity of the sub grade soil that q e. So, we can write that q e is equal to P 0 is equal to pi into c u plus gamma of h 0, because we consider that cello foundation theory of geo trainical engineering. And we assume the soil is undrained condition, and soil is saturated fine grain soil, plane soil, arcane silty soil, and also it is a compressability of the foundation soil for unpaved road.

So, without geosynthetics material maximum pressure, that can be maintained corresponding to the elastic limit of the soil; that means, elastic limit. That means, P 0 will be equal to pi into C of u, so elastic limit of the soil means P 0 is pi into c u plus gamma of h 0 that mean q e is equal to pi into C u plus gamma h 0. Now, what C u is the undrained shear strength of the sub grade, now again that you can write that P 0 will be equal to P divided by 2 into B plus twice h 0 tan alpha 0, L plus twice h 0 tan alpha 0 plus gamma of h 0.

So, from this and this equation you have to calculate what is C of u; that means, C u will be equal to P divided by 2 pi, because pi is here. So, 2 pi into b plus twice h 0 tan alpha 0 into l plus twice h 0 tan alpha 0 and gamma h 0, gamma h 0 will be cancelled from both sides, so from this and this equation you can calculate what is C u.

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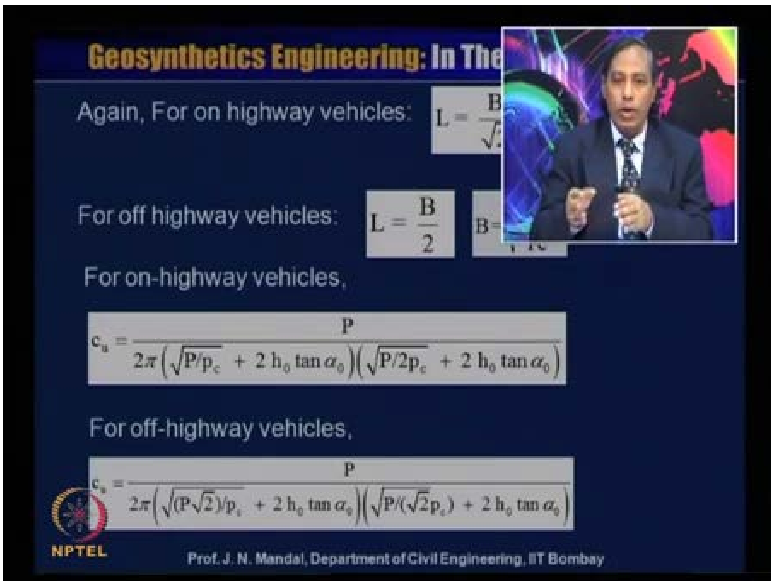

So, you are having the value of C u, now that if it is a on highway vehicle, so L will be equal to B by root 2, and B is equal to P divided by P c, for off highway vehicle L is equal to B by 2 or B is equal to root of P root 2 divided by P c. For on highway vehicle C u is equal to P divided by 2 pi root over P by P c, because that is the P plus twice h 0 tan alpha 0 plus root of P divided by 2 P c plus twice h 0 tan alpha 0. If it is a for off highway vehicle, then C u will be equal to P divided by 2 pi, then root of P root of 2 divided by P e plus 2 h 0 tan alpha 0 into root of P, and then root of two P e plus two h 0 tan alpha 0.

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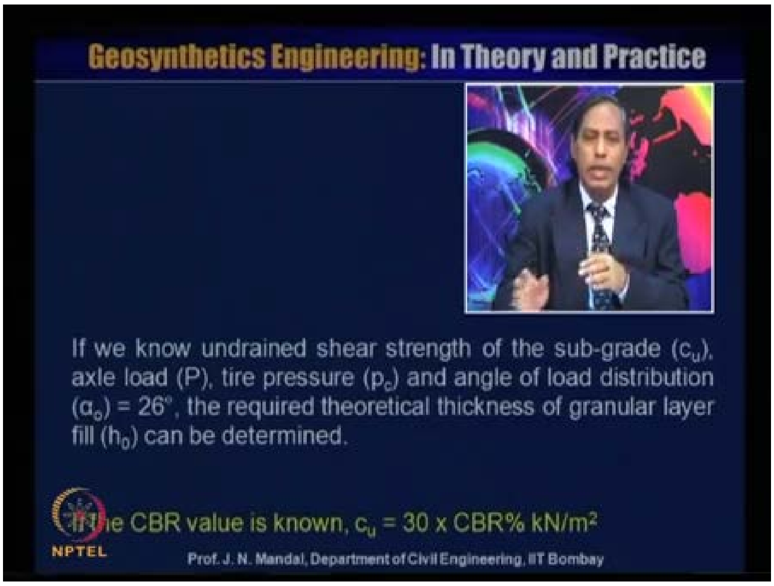

Now, if you know, that what is undrained shear strength of the sub grade; that means, C u if you know the what will be the axle load P, you know the tire pressure P c, and the angle of load distribution alpha 0, that is 26 degree. The required theoretical thickness of the granular layer fill h 0 can be determined, and if the CBR value is known you can calculate the what will be the undrained shear strength of the soil, that is C u is equal to thirty into CBR percentage that is kilonewton per meter square.

So, you remember that this is the unreinforced case, how you can calculate the thickness of the pavement, so this is the equation which we will adapt for the design of unpaved road without geosynthetics material. And also we will adapt that maximum pressure that can be maintained, that is should be within the elastic limit of the soil, but in case of the reinforcement, where we will introduce the geosynthetics material. Then limiting pressure can be increased to the ultimate bearing capacity of the soil, then this equation will change which we will discuss the later.

So, we should understand first of all that how to design the pavement without geosynthetics material, and what should be the thickness of the pavement. First of all that you should know what will be the severe value or the undrained shear strength of the soil, and at the same time you should know whatwill be the tire pressure, and then you can calculate that what should be the thickness of the granular layer field. With this I ended up this today's lecture, let us hear from you any question, and… Thanks for listening.