Ground Improvement
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Lecture No. # 37
Geosynthetics in Pavements

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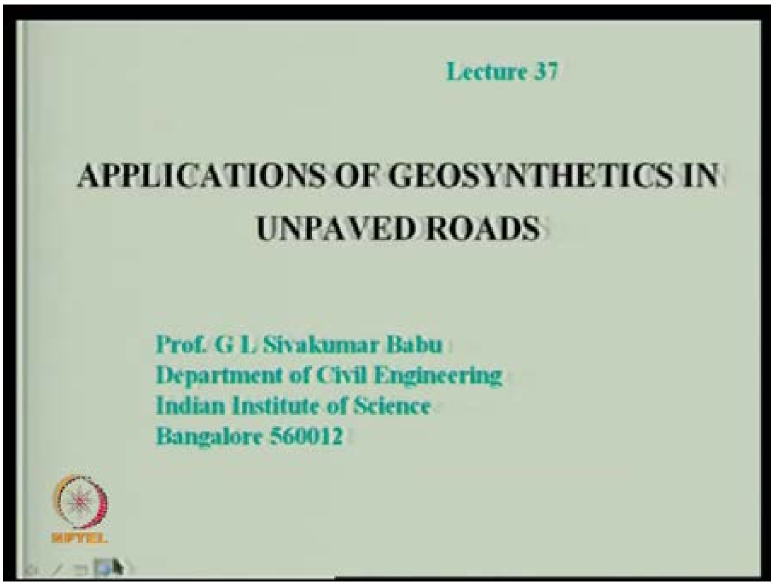

We would be talking about applications of geosynthetics in unpaved roads in this lecture.

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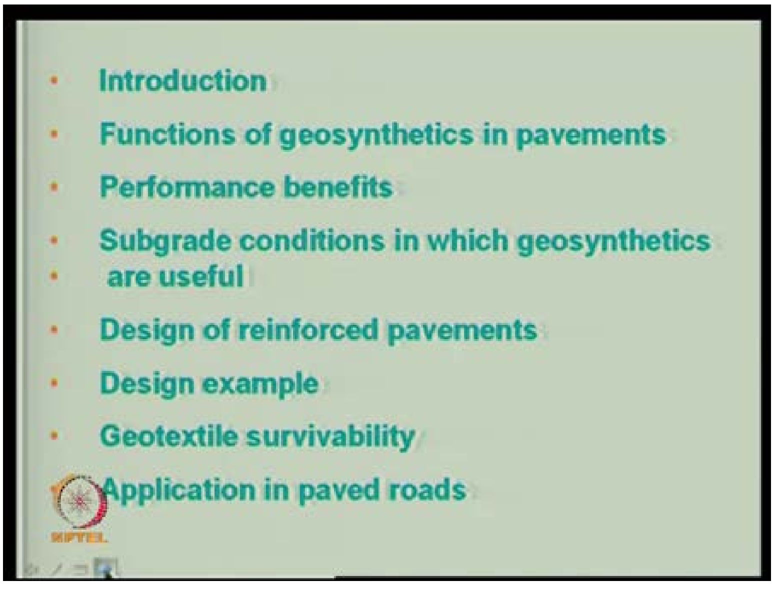

And essentially this, when the soil is poor, we try to if you want to design the road, you have a you do the CBR test, which is nothing but a strength test. And we try to see that, the thickness of the pavement is arrived at based on the CBR value.

But in some cases, there are many other issues that, like still there could be many other problems associated with readability and comfort, and many other issues like performance; it is very very important, that some of these aspects are considered in the road design. What we will address today in this lecture would be that, we will study the why this geosynthetic materials required in roads.

Actually there are two types of roads, one is called two types one is unpaved road and paved road. Essentially unpaved road means, just there is no treatment to that, and then we just the soil is very poor, but you try to make up by making some sort of crust over it. And then, we make like some thickness that you get based on CBR value; we know the in situ value of the in situ CBR value and then you try to put some sort of cushion, because the CBR is so low. Then, we try to add some more like a granular sub base layer - GSB we call it.

We normally have the sub grade and then the sub base and base course. And after that, you have a wearing course. So, all these, I mean, below this wearing course, it is called unpaved section, ok.

So, we will see, what is the use of this geosynthetics in pavements, their performance benefits, and this conditions under which the geosynthetics are very useful, how do you design this pavements, and we will have an example here and what about the survivability criteria and some application in paved roads.

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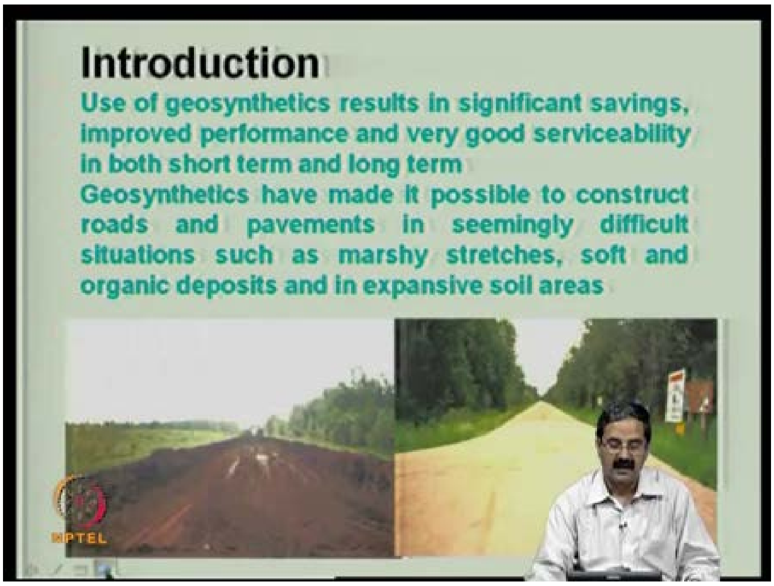

As I just mentioned, this is like a typical road section, which you see that it is very difficult to do, that any you know. So, you have the soil sub grade is you know so poor, but then based on the CBR value, you can come up with some sort of thickness and then you can make it unpaved road. After this, again you have a pavement layer constructed on that.

People have seen that, the geosynthetics help in significant savings, improved performance and good serviceability; both in short term and long term. These are very important, like savings is one thing; then, improved performance I was talking about readability and comfort smoothness on the roads; this is very important and long term performance like serviceability is also very good.

So, all these three things are very important in pavement design using geosynthetics, and this is where the they are very useful. And other thing is that, even in some conditions - very difficult conditions, like marshy stretches, very soft soils, organic deposits and expensive soils, one can construct; that is a very good advantage, that it is very difficult to handle them, but at the same time, if you these materials, one can use, one can construct good roads.

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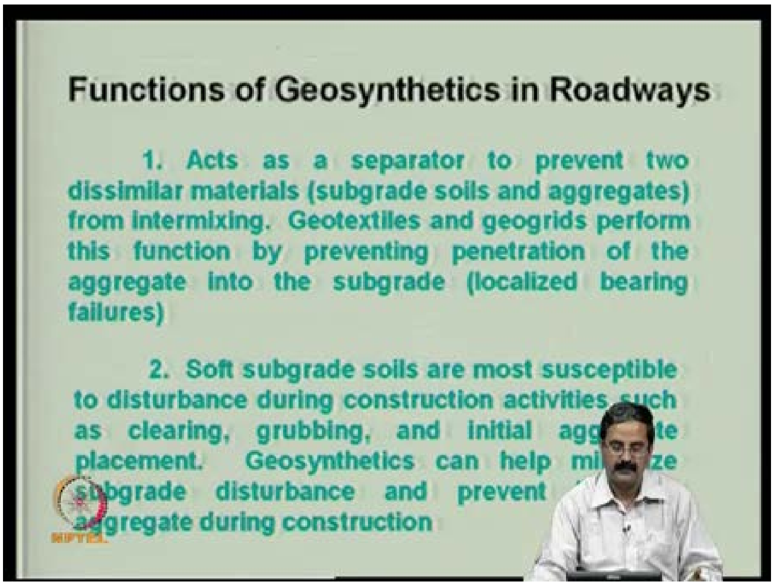

How do they help? So, the functions of the geosynthetics in road are, that like it acts as a separator. As I just mentioned, you have two dissimilar materials like sub grade and aggregates; you try to see that they do not get intermixed. So, geotextiles, geogrids perform this function by preventing penetration of the aggregate into sub grade, it is called localized bearing failures.

In fact, what happens? There are two dissimilar materials, the bearing capacity of you know what you call the subgrade is, we have some bearing capacity. And if you put at, even a if you put a granular sub base, the bearing capacity increases; you know GSB or the granular sub base as a better bearing capacity, because it is a moreover frictional material.

So, when you have that, but then over a period of time, because of the repeated action of traffic, repeated action of loads of tire because of the traffic movement, the sub grade material goes up and that aggregate material comes in. And then, there is intermixing of both materials like bad plus good becomes bad, you know, it is like that.

So, essentially that is a very not a correct thing, and if you have a separator between them, each will perform their functions in a very satisfactory manner, with which you know, you must have designed based on those lines, like you must have taken a CBR value, sub grade and you get a thickness. So, we do not assume that, there is a mixing up right. So, that will not happen now.

The second thing would be that, soft sub grade soils are very susceptible to disturbance during construction activities, such as clearing, grubbing and initial aggregate placement. Geosynthetics help in minimize sub grade disturbance and prevent loss of aggregate during construction.

In fact, to during construction, they are quite affective, like you know, say in some places like soft soils, it is very difficult to clear them; clearing and initial aggregate placement, like as I just mentioned in the case of other examples, like if you try to put aggregate, it gets mixed up; and you know you may lose some thirty percent of the aggregate, just to see that you have some hard material in the beginning.

So, but if you have a geotextile, exactly you know the quantities of aggregate you have placed; that way the contractor would not claim, that there is a loss of aggregate for me sir, and there is no problem here. So, that they help in that prevention of loss of aggregate.

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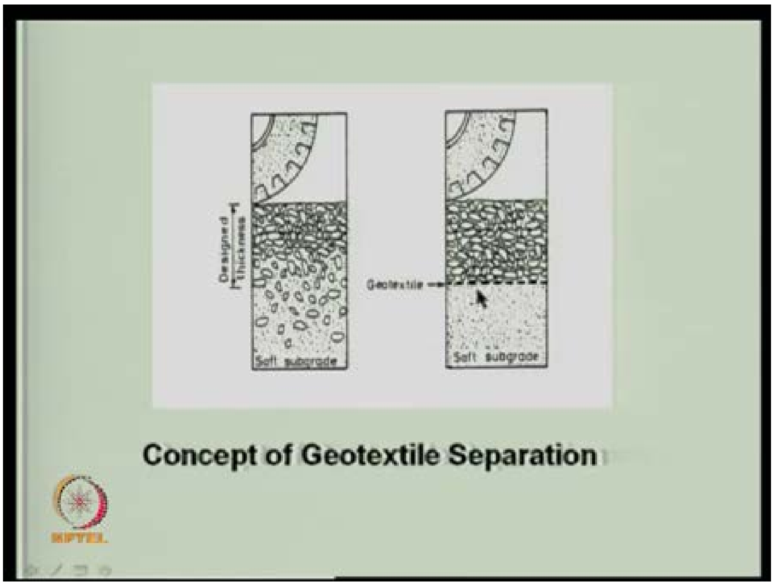

So, this is what I just mentioned, like, you just have a soft sub grade, you have a geotextile and they behave in this way, rather than this way, right, where there is a mixing up is here, right.

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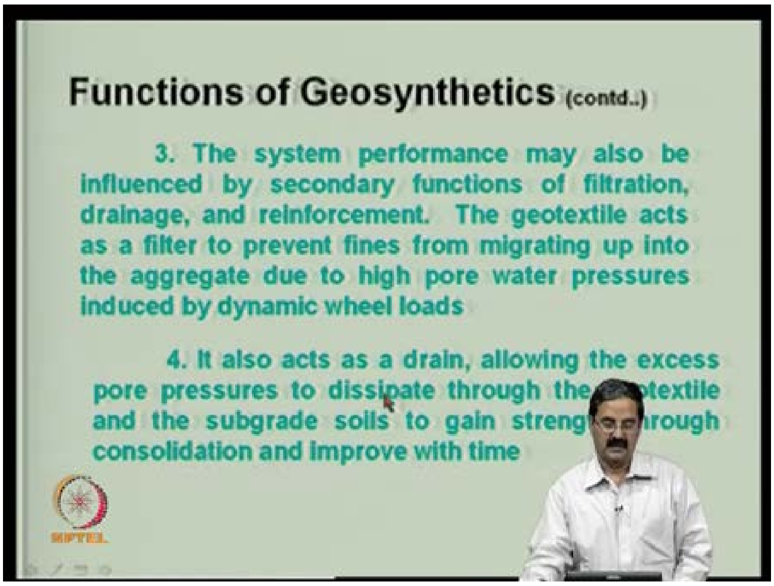

So, the other advantage that we have is that, we have a geotextile, its nice, but you know it is a separator function right now, but it helps as a it has functions of filtration as well, as well drainage and reinforcement; all of them will help. So, geotextile acts as a filter to prevent fine particle from migrating into the aggregate layer, you know, due to high water pour pressures induced by dynamic loading.

Then, it also acts as a drainage, you know, you are trying to put it to the side drains also; you can take it and then put it drain layer nicely. So, pour pressures are dissipated and also that you can provide some sort of drainage as well.

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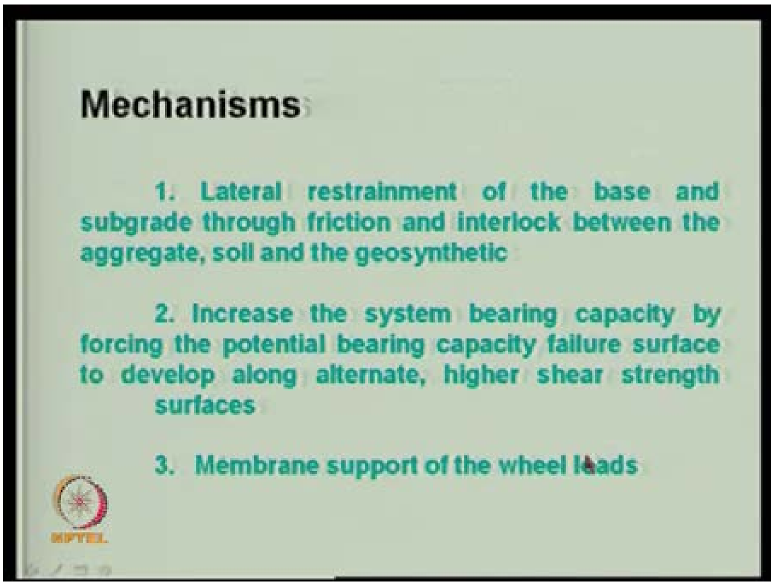

So, these two and say even reinforcement also helps, and the way that reinforcement helps we will see that, say for example, as I just mentioned, like confinement effect; we talked about inward shear stresses and outward shear stresses concept in embankment and soft soils; here also same thing, there is a lateral confinement of the base, and sub grade through friction and interlock between the aggregate soil and geosynthetic.

Because of the interaction between the geograde and aggregate and soil, the there is some inward lateral restrainment or the inward stresses, because of which there is some confinement effect inside opposite direction. The load is applied, but the force is in the opposite direction. So, it performs better than a conventional – geo-conventional - pavement system.

So, the other one is increasing bearing capacity by the forcing the potential bearing capacity failure mechanisms, to go along alternate higher strength surfaces. The third one is the membrane support of the wheel loads.

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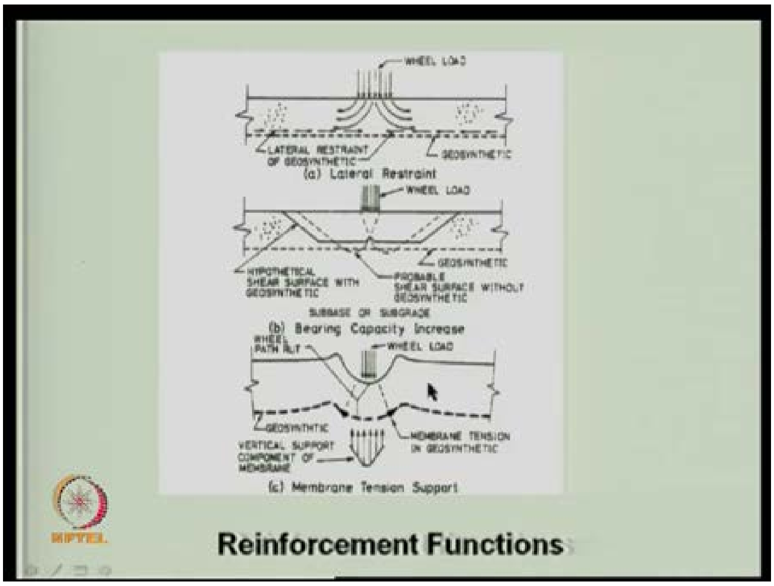

I will give you the example, like this is a wheel load it is acting and there is a pressure like this. And because of this, there is you have placed a geogrid here and there is a lateral restrainment in both sides; this is what we call confining effect. The second thing is that, we assume some sort of failure mechanisms like this, bearing capacity failure mechanisms, and if you put a reinforcement here, there is a possibilities are these failures surface gets altered.

You know it is a new failure surface which can be a different, and the shear resistance along the failure surface can be much higher, you know, because it gets deflected away from the original one. So, if we just take the length, length of the failure surface will be bigger, and along the length of the failure surface, the shear resistance is also more.

So, we take that assumption, and then calculate the load bearing capacity of the sub grade here the other one is. So, this is called bearing capacity increase. The first one is lateral restraint; second one is bearing capacity increase; the third one is membrane tension effect.

Particularly in soft soils and there is no friction between the soil and reinforcement; what happens, like you know, there is a you know when there is force load applied, it gets like a it is a tension membrane; membrane gets deformed and the force in the membrane acts like this, that the vertical component of the, you know, vertical support component of the membrane resist the load in the load load from the top, like you know, the membrane tension in the geosynthetic, it acts like this.

So, there is some resistance here; though we do not assume that, there is a so much of interaction, just because of the membrane like a balloon, right. So, this is actually also valid in a case of very soft soils and all that, where the friction is quite less. So, all these three mechanisms can be very useful to calculate, what should be the effect of reinforcement, right.

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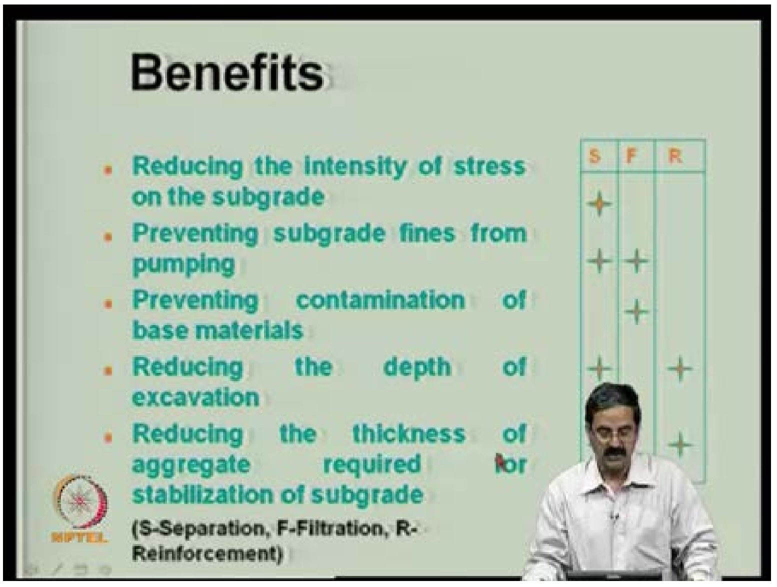

So, how do you understand this benefits, like say for example, this is separate function, separation function, filtration function reinforcement. Reducing the intensity of the stress on the sub grade, the separator function helps. Preventing the sub grade fines from pumping, both separation and filtration helps. Preventing contamination of base materials, filtration helps. Reducing the depth of excavation here, separation helps and reinforcement also helps.

Reducing the thickness of the aggregate required for stabilization of sub grade, separation and reinforcement help. So, the mechanisms of use or the benefits, you know they are like this. So, these are a very useful things like, say for example, you would like to reduce the thickness of the aggregate layers or whatever, thickness of the crust or that pavement, these two will help us, like separation function, reinforcement function; these are all extra benefits that we have. So, these we try to quantify here, because it is possible for good design, design procedures are possible.

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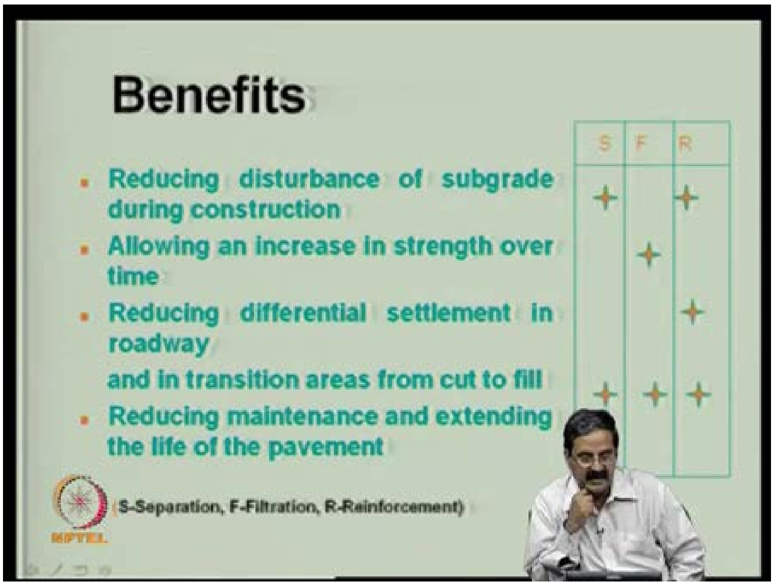

And other thing that we have is the disturbance of sub grade construction; during construction is less and that is in fact supported by separation as well as the reinforcement function. Allowing for increase of strength over time, yes, filtration, because it enables the drainage effect, it is possible. Reducing the difference settlement, reinforcement function helps, because that is one important thing.

In the transition areas from cut to fill, again it helps all the three things help. Reducing maintenance and extending the life of the pavement, all of these materials help in some sense in giving the benefit of the performance, right. So, this is ok.

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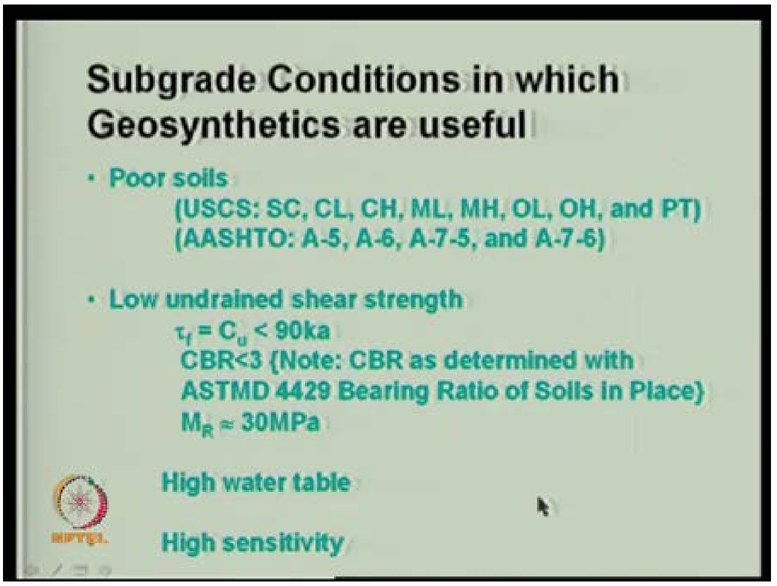

Now, what are the conditions under which the geosynthetic materials are useful. In fact, if it is a very poor soil, excellent right, like all the soil classification like is based on the USCS classification, and like CL CH ML, all these they quite useful P T soils also. And actually in AASHTO code, you have A 5 to A 6, they are all very poor varieties of soils. If you just say AASHTO code, the lower numbers say for good soils; the this for poor soils. And if the untrained shear strength of the soil is less than 90 k P a and CBR is less than 3.

Actually I want to just give a simple correlation here, which is available in literature, 1 k P a is equal to sorry 1 percent of CBR is equal to 30 k P a roughly. And if the moment of the resilient modulus is what is another term that we have, it is less than it is close to 30 M P, its also quite useful.

And in high water table area is also, they are helpful, because of the drainage and all that. Then, high sensitivity is also they are quite useful, where their sensitivity is quite high in soil, since they are helpful.

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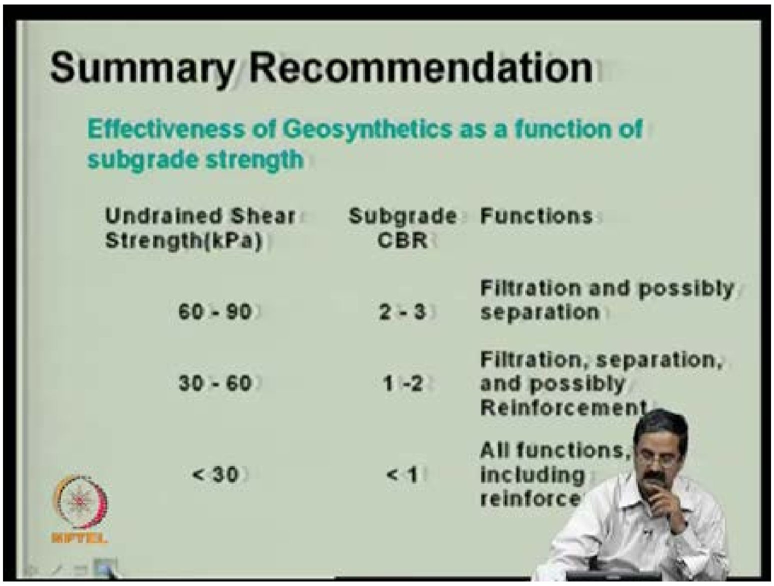

So, how they are effective? To what extent they are effective is the function of the sub grade soil strength. If the soil sub grade is, no like you can find out a vane shear test or a C u test, you will get the untrained shear strength, say 60 to 90 k P a, as I said CBR will be in the range of 2 to 3, you, know because 1 percent CBR equal to 30 k P a. So, at that time, the functions like filtration and separation are very helpful. And if it is somewhat lesser weak, you know, like you know, this is a somewhat stronger in this group, and if this CBR is between 1 and 2, filtration, separation, possible reinforcement action may help.

But if the soil CBR is less than 1 percent, all mechanisms of improvement are very useful, like he can designed a pavement based on IRC guidelines or whatever; one can design, you know, depending on one percent CBR, what is the thickness of the crust required one can calculate. We will show some calculations on these lines in this lecture today.

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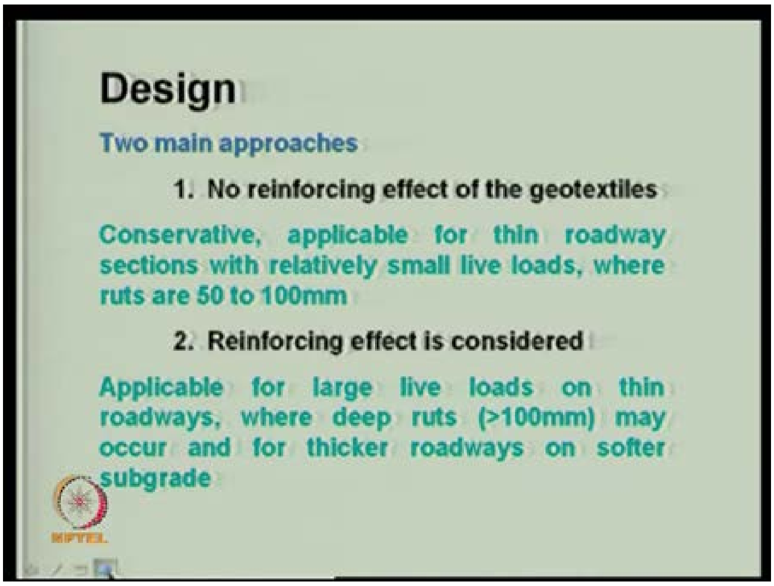

So, how do you go about design? It is design is that, like as I just mentioned, the reinforcement helps in the prevision of a geotextile helps in two ways; it acts as supporter and it also acts as a reinforcement layer. So, first thing is that, I do not want to take consider the reinforcement effect; I will only make it, I mean, I assume that it works as a separator, right. So, in that case, we will we will have a design procedure that we will see and it is quite useful. Then, you will also the you are you know about red depth.

Red depth is nothing but a permanent deformation in the soil, like you know, if there is a, like say for example, I want to give an example, if there is a vehicle continuously going, there will be a depression, which is called permanent depression; it could be the maximum depth of rut could be about 50 mm to 100 mm in some cases. So, you can, when the rut depths are small or loads are quite less, like you know, say simple village road, where there is not much traffic and its fine; one can take a geotextile, which can just work as a separator.

Anything which can work as separator, our objective is to see that they do not get mixed up nothing else. So, you know, you can use any material that can serve the function, but durable right. So, that is one thing. So, that can be very useful for thin sections or where that traffic loads are less, and also the rut depths, you know, rut depths are like quite less, ok. Like you want to rehabilitate a road, say for example, which has lot of vehicle, tracks, and you know, you must if you go in a village, you see that, along the track, along the road, there will be some depression, that is called rutting.

So, that is one thing. The second thing is, if you put a somewhat stiffer material, like, a instead of a I want a geogrid which is somewhat stronger. So, I will be able to take advantage of that; and then, I can use it for live loads which are higher and rut depths are also higher, like as I just mentioned, the rutting depth what is that membrane effect. Membrane effect is there, higher is depression that you have, higher is a tensile force mobilized. So, if you want to really handle depths of ruts being a higher, you need to have higher tensile force. And it may consider thicker roadways on sub grade and all that, right.

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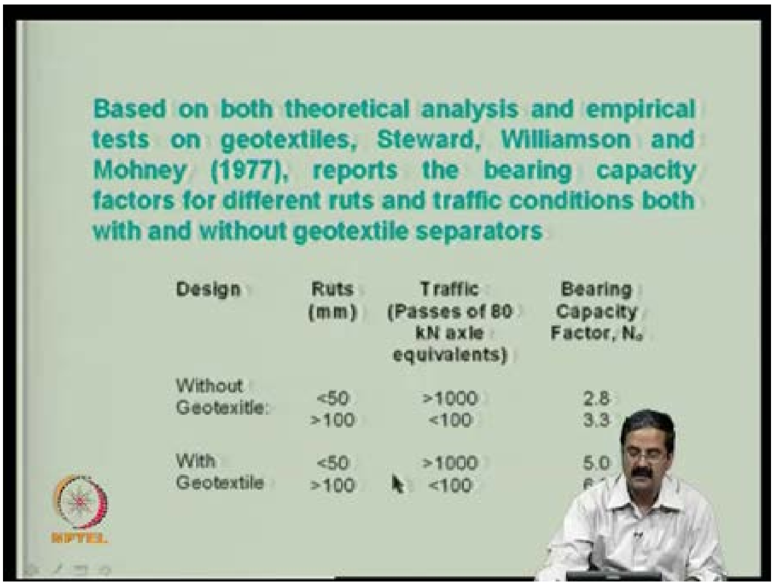

So, the some more style is that people have done and people he did x lot of field studies as well on clays, and like if the traffic, you know, we know that the what is the standard load, its 8 tons; you know in a Indian standard code, its 8 tons or 800, 816.

So, 8 its 8 tons, we call it 80 kilonewton per mater or 80 kilonewtons; actually 80 it is not meter actually 80 and 80 kilonewtons. And or it is also same as even in US code, the same thing is done, and without geotextile into the rut depth is few less than 50 mm, and the traffic intense is more than 1000 mm; people have worked at bearing capacity.

I know I hope you know that the bearing capacity of soft soil is 5.14 C u, right. If you know the Q U equal to 5.14 C U. So, that is the ultimate bearing capacity of the soft soil. So, what does it mean? 5.14 means, it is a ultimate strength has reached, right. So, if anything less than that, actually that what is that 5.14 is nothing but the bearing capacity factor. So, what without geotextile, if the rut depths are in this range of less than 50 mm, people have seen that the bearing capacity of factor could be in range of 2.81; one can work back, ok.

And geotextile you know its rut depth is more and traffic is less, its 3 point; there are some empirical or you know the some reports that people have presented, and with geotextile less than 50, the same number 1000 its bearing capacity is the factor is 5. And then if the rut depth is there, it is little increasing; actually this gives an interesting observation, that roughly the bearing capacity with and without geotextile, there is an increase, right. So, for example, you take only a rut depth of 50 mm, less than 50 mm, the bearing capacity increases from 2.8; factor 2.8 to 5, it increases from 3.3 to 6 it increases, this is a very important observation.

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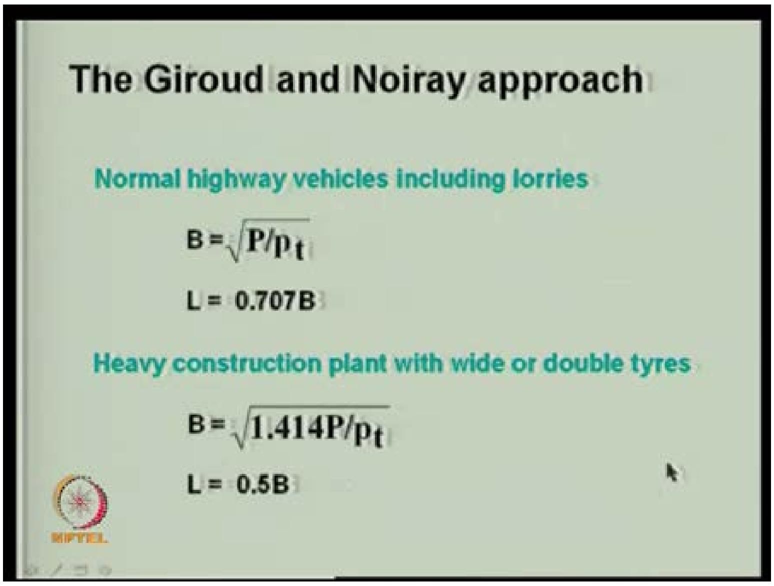

And that is useful in the actual approach - theoretical approach - that we have. In fact, Giraud and Noiray approach is one of the popular approaches that people have worked on earlier. And it is in developed in 1978 in an ASCE paper, and of course, there are lot modifications, but for the case of simplicity. I have I am trying to illustrate this method by use of the design of this pavement by this method, ok.

Actually you have a normal highway vehicles, it creates a bearing, you know, you have certain load over which that traffic load acts, that is given by, say for example, B is the one dimension breadth; the breadth its nothing but the applied load P, P is nothing but the standard axle load divided by the tire pressure, right.

So, B is call it a P by P t and so L is nothing but 0.707 times B; and this is what is that it is an impression of the area, of area over which the load is acting. The second thing is that suppose you have high construction equipment, definitely you have wide or double tires. B you can write in this form, B equal to square root of one point, it is little bigger P by P t and B l equal to 0.5 B.

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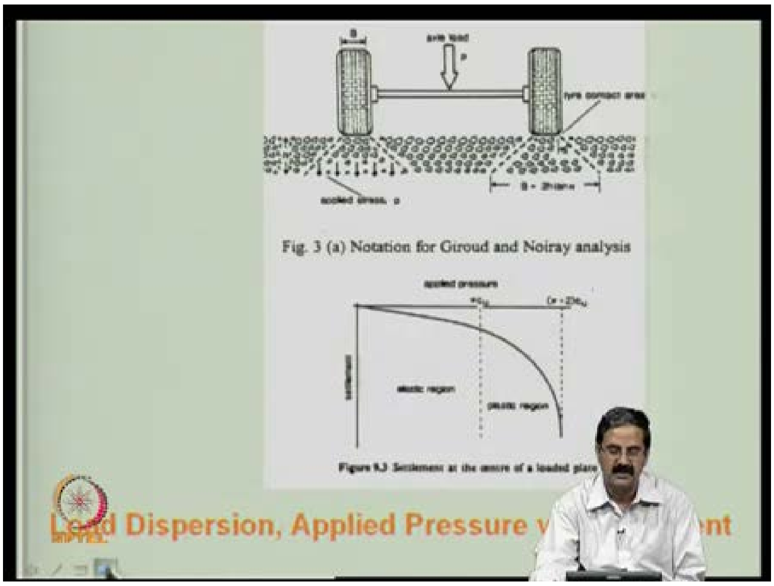

So, this is another way of approach that they have proposed. And the how is that load is acting here, say, suppose I put a reinforcement, how does it work? Actually what I am doing is that, see, there is a you know you apply a standard axle load here; this a B is a dimensions and the L is in the the perpendicular to that.

And we assume some dispersion angle, right; this is the standard you know in, say for example, stress distribution we assume. And we assume that. when you apply, you know, the you consider the load displacement curve, like this is settlement, this is applied pressure. And you know that, I told you that, it increases to 5.14 C u, right, pi plus 2 into C u; soft soil is the ultimate bearing capacity of the soft soil, why you are talking soft soil? Soft soil is poor, actually that is the reason CBR is slow. So, this comes to 5.14 C u is a fully plastic region, ok.

Then, this is we just come up to a region, where its soil is elastic, and we do not go beyond that. And we assume that, though there is a nonlinearity here, we assume that the soil is linear up to this point - up to a point pi C U. So, the elastic limit of the soil is given by pi C u; the plastic limit of the soil is given by pi plus 2 C U. So, this is all the elastic region, this is the plastic region, because the deformation starts accelerating from here.

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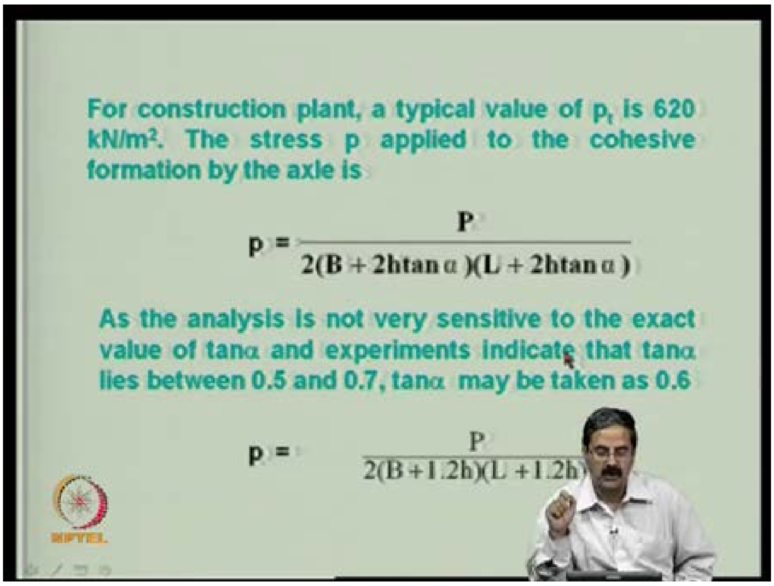

So, how do you go about this? Say for example, we know the tire pressure and all that, and how do you take the load. In fact, P is nothing the like, we have seen in the previous diagram, you have applied a load P; and what is the load that is coming here is what you should calculate. So, in fact, if you take the load dispersion angle, this becomes B plus 2 h tan alpha, where alpha is a angle of dispersion, right; this is h tan alpha and this is h tan alpha, so twice; so, B plus two h tan alpha you will get.

So, whatever is the load that comes here gets reduced, because it is now where a wider area right. And if that, so we will see this how this becomes converted into what we need. So, P is nothing but P divided by 2 into B plus 2 h tan alpha into L h tan alpha; this is the the terms, ok. So, the total pressure gets divided P by 2 into this is what you get. So, the as the analysis is not very sensitive to the exact value of tan alpha and experiments indicate that tan alpha lies between 0.5 to7, alpha may be taken as 0.6. The dispersion angle that we have in the angle alpha is not very sensitive to this and then we can take it as 0.5 to 0.57, average is 0.6. So, if you do that, and that will get into B into 2 is B plus 1.2 h in this expression; you will get, right.

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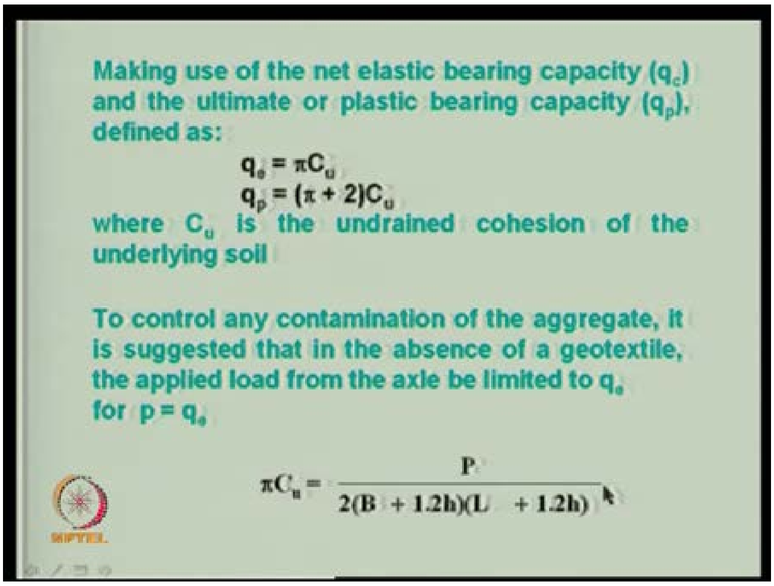

So, as I just mentioned, the bearing capacity - elastic bearing capacity - is pi C u, which is q e I call it. Then, q P is pi plus 2 C u, where C u is the untrained shear strength of the clay. Now, what I do is that, I do not want any mixing of the aggregate and clay; and if I maintain the loads within elastic range, the possibility is that the soil is also elastic and aggregate is also elastic. So, there will not be much mixing. So, they come back to their original deformations and I do not have any problem of mixing; but so, what I do is that, I will try to calculate that load, you know, it is suggested that in the absence of geotextile, I am not putting the load. So, I will like to limit the load to just q based on elastic limit.

So, pi C u is nothing but that value, and I just mentioned P divided by. So, this is the load right now with geotextile, it is a load at which it is acting; you know the this load now is coming on the sub grade, right, pi C u is equated to this.

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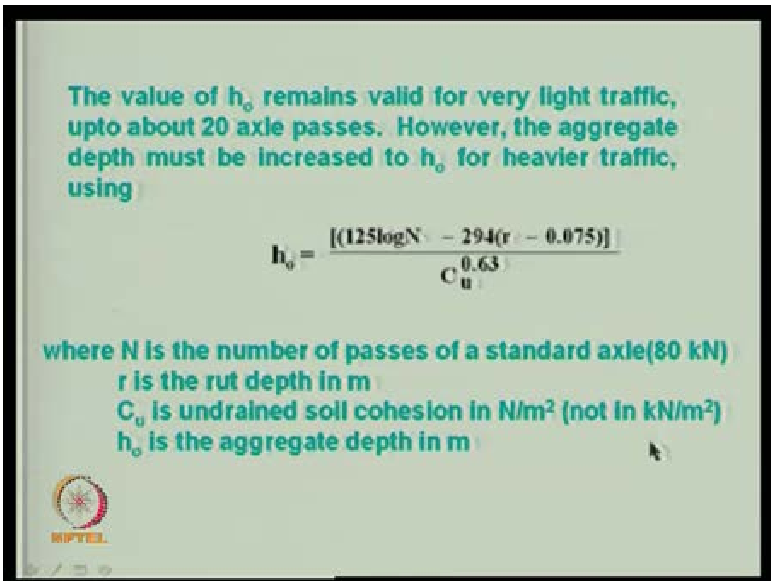

There is one thing, like for example, that equation whatever I have given just now, helps you to calculate, if you know untrained shear strength, say for example, 10 k P a if I say or 5 k P a I say, and load I know P axial load I can get h value, right; it is a very nice example on how to get how much of thickness I have to provide; only thing is that I have not provided the traffic load repetitions. So, how do you do that? That whatever we have see in the previous expression is valid for light traffic and small repetitions of loads, but when the load the aggregate depth must be increased, because when the traffic load increases, definitely you have to increase that.

So, we call that as h 0, now the revised h 0 becomes this expression; you know, people have done lot of experiments and came out with this expression, which is in terms of the load number loads repetitions N minus 294 in 1, r is called a rut depth, ok. Rut depth in excess of 75 mm, whatever; rut depth in whatever the units, you have to put in the appropriate units here; C u is in newton per mm mater square. So, if you know this number, then it also takes care of, say for example, this will be you may get some h in the previous value, but this h will be little higher, because you are considering the traffic load as well, that is one thing.

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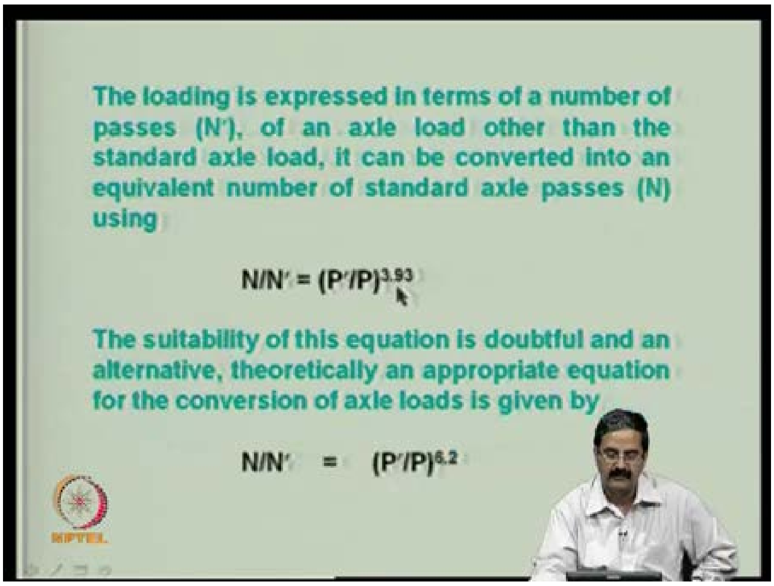

So, we know how to calculate the thickness without thickness of the what is called the pavement, without what you call much traffic, like if the traffic is very limited, I know how to get the thickness of the pavement, but if the traffic is more, and if I know the load repetitions and rutting depth allowable rutting depth, I know the h 0.

Now, the other one is that, we are trying to put in terms of the standard load, you know, standard axle load. Most of the time you have the vehicle axle, the the axle loads are different from standard, like instead of 8 tonnes, it can be 12 tonnes, 16 tonnes, all that, right. So, what happens? Because of the repeated nature of traffic, the possibility is that it undergoes high deformation than what you expect.

So, one should really convert all the higher load effects into standard axle load. So, how do you do that? You have an expression here N by N is a standard axle load by N dash is a non standard axle load. So, for example, 12 tones, 12 tonne standard axle is 8 tonnes.

So, in this case, P dash is 12 tonnes and P is 8 tonnes. So, if you just put these numbers, and then you know the the P dash is non standard and N dash is non standard. So, both these loads 12 tonnes and we know the repetitions, how many, you know, you do a survey (( )) evening how many (( )) are there, which are of non standard quality - non standard specifications - like axle load essentially.

And you can convert using this equation as non standard ones to standard ones this is one type of equation that people have being following. In fact, ICR code also to some extent follows this, because this is a based on the deformation criteria and all that, but some more advanced some more research says that, a ratio of 6.2 is much more safer, that is one important point. So, this also helps in calculating the load repetitions of standard load, given that, you know N dash and P dash.

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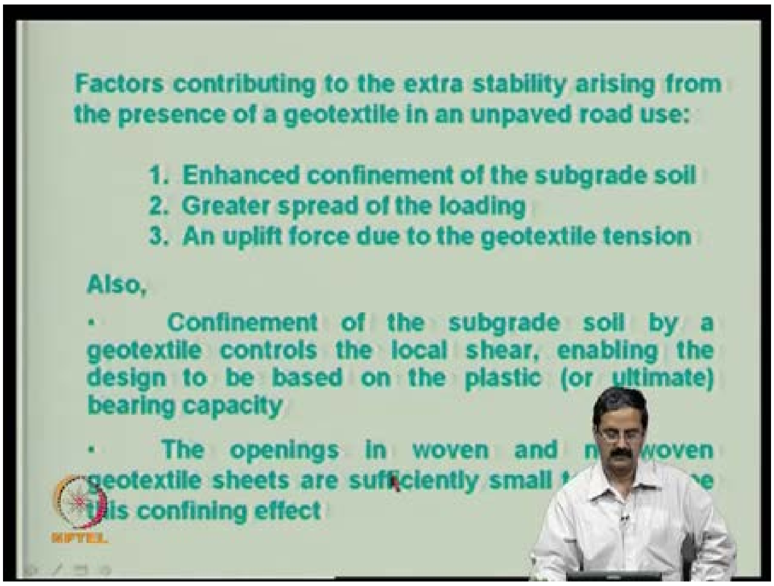

So, what is that we are working here is that, the geotextile helps in confinement of the sub grade soil, greater spreading of the load, and like as I said, geotextile works in tension, right, geotextile works in tension. And the confinement effect of the sub grade is very useful that we have seen, and the openings in the some of the geotextiles and geogrids definitely provide this confinement effect.

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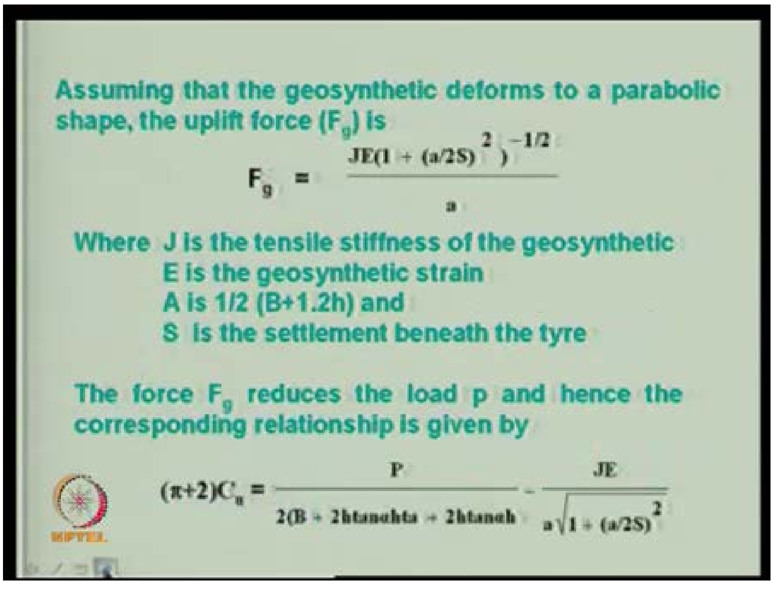

That is when we have seen that, we know how to take care of it. And assuming that, geosynthetic deforms to a parabolic shape, like we have an assumption. So, the thing is load, that is there in the what is that, you know, because of the membrane effect is what I am trying to put here, that is given by F g.

You know the thing is that load is acting like this; the tension in the geogrid action is direction and how much of tension you have to calculate is in this form load, load due to that uplift force, is nothing but it is the function of, actually it is a J E into 1 plus a divided by 2 S square, it is power minus half into a, where J is the tensile stiffness of the geosynthetic; a E is the geosynthetic strain actually, it should epsilon or whatever. So, it is a is a is the factor, which is 1 by 2 into B plus 2 h B plus 1.2 h, S is the settlement of the beneath the tire.

The F g reduces a load P and hence the corresponding relationship is given by, you know, what is happening? The load is reduced; this equation we just gave, because of that previous, you know, the the like without this this term is because of the pension; this is because of separation function.

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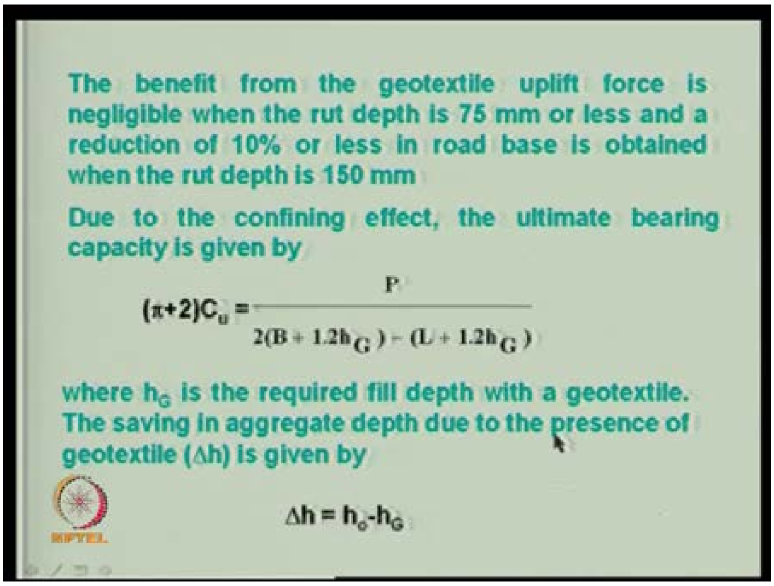

So, what we assume is that, by we equate it to pi plus 2 C u; we assume that its we assume that, its equal to pi plus 2 C u; and what we are assuming is that, I told you one simple assumption that, the elastic limit it is the load is pi C u and it becomes pi plus 2 C u at the plastic limit.

Now, with introduction of load, I will say that load can be taken from elastic to plastic only, because the contamination is not there now. So, I what I say is that, whatever is this total thing with a geotextile now, you have a h G as, because of the geotextile, that is equal to P divided by the same thing; and the I equated to pi plus 2 C u instead of just in the previous one. What I did was, I just equated to pi C u only, because then I assume that, there is no geosynthetic.

Now, I have a geosynthetic material and I assume that I can contamination is not likely to occur, because the soil is not now, you know, they are all you know separated. So, I can safely take that the load, that maximum it can be applied is pi plus 2 C u. So, there h G is a thickness of the membrane, you know, thickness of the fill. So, how do you get the savings now? What is the savings in geogrid thing is that, you know h 0 is the thickness that you got considering, traffic load repetitions and all that, you know, that is h 0, and h G is the geogrid how much is that. So, h 0 minus h G will be giving the savings in the aggregate, ok.

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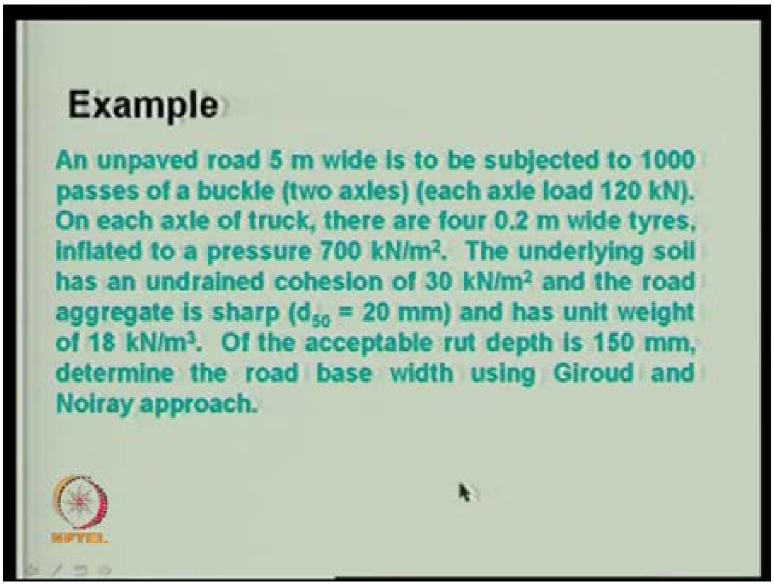

I will show you this by means of an example, that may be much clear; an unpaved road like it is about 5 meters wide is subjected to 1000 passes of a buckle or whatever, you know, you can say two axle loads like, you know, some small vehicle and each axle load is 120, you know, 120 kilonewtons; it is little higher than 8, 8 kilo 80 kilonewtons which is standard. And each axle of the truck, there were 4; its like you have an axle, there are 4.2 wide tires inflated to a tire pressure of 700 kilonewton per meter square.

The underlying soil has an untrained shear strength of 30 k Pa and the aggregate is sharp; why this things are required is, in terms of the serviceability specification this is required, and has a unit weight of 18 kilonewton per meter cube. If the acceptable rut depth is 150 mm, determine the road base width using Giraud Noiray approach, that is the question.

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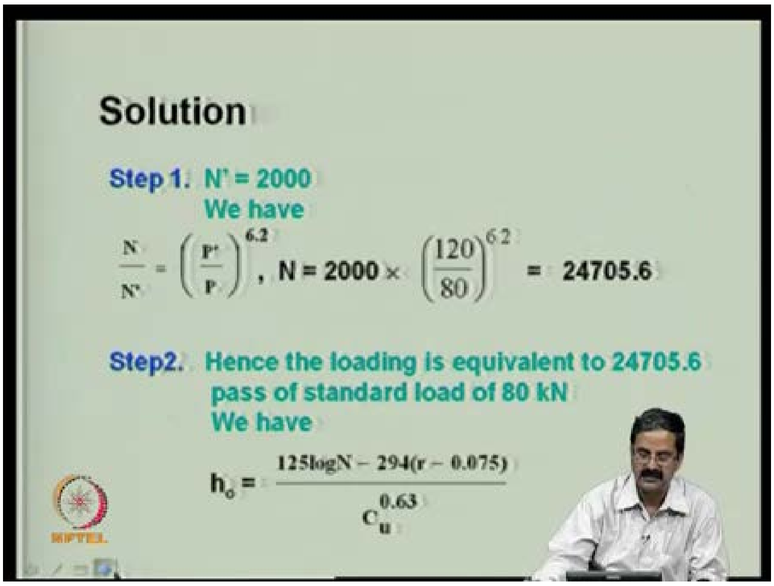

So, what we are trying to do here is that, so N dash we know, N dash is 2000. So, the we know that its 80 by 120 is what you have to put, and as I said 3.93 can be used. But I am using a factor of 6.2 here to get the equivalent load repetitions; you can see that it is a very the significant 120, 2000 repetitions of 120 kilonewtons are equivalent to 24000, nearly 25000 load repetitions is 80 its very high, because of this factor 6.2. So, you can see that the damaging effect of what is that higher axle loads.

So, the loading is now equivalent to this 24705.6 passes of the standard axle load of 80 kilonewton. Hence, I am using this term h 0 is one thing that I said earlier. And use this term now here, like this term comes here, rut depth is also known and C u is known.

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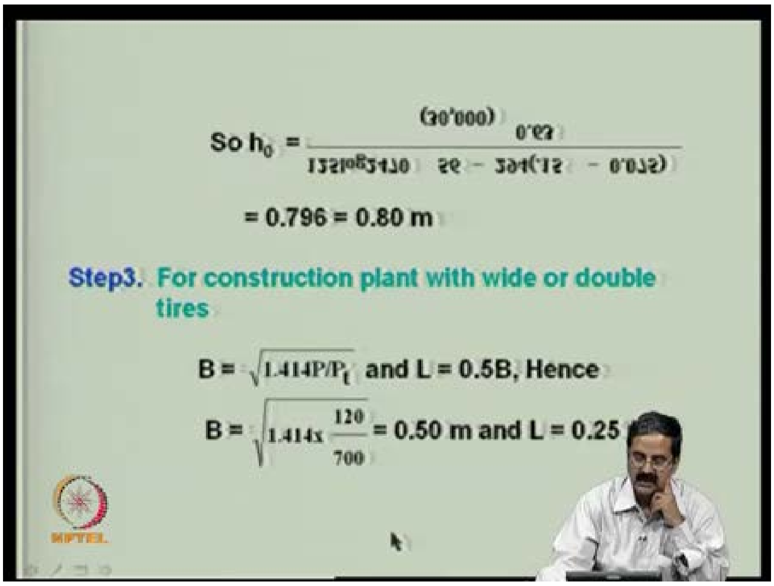

This some error here I will revise this equation. So, it comes to 0.8, 0.8 meters if you just substitute all the terms, and for the construction plant and with wide or double tires, you know, suppose I am using a you know construction plant, these are the equations that I just mentioned.

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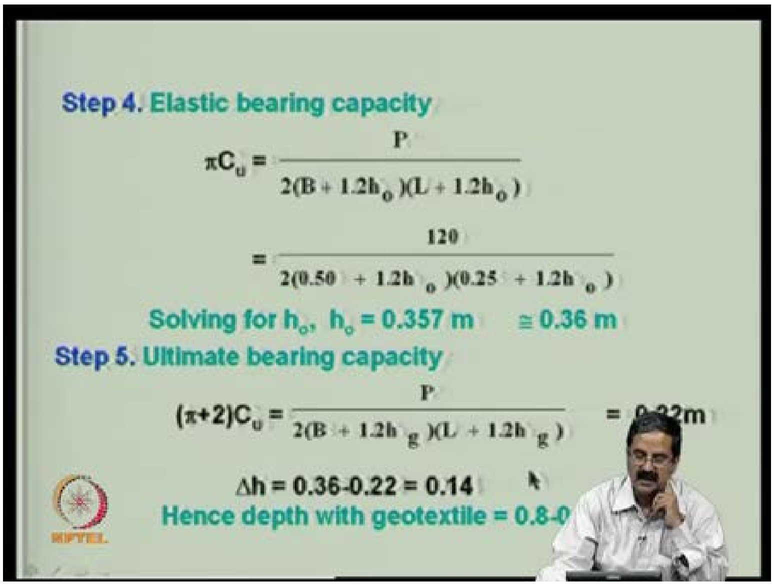

So, you know what is the thickness of the road now, say for example, in the previous case, we have seen that it is a using all those equations, you get 0.8 thickness. Now, I should get what should be the thickness, if I use geosynthetic, that is a question. As I just mentioned, I know equate it to elastic bearing capacity pi C u; P is a standard load of 120, and I use B into B plus 1.2 h and all that I, I calculate and I get in solve for h equal to h 0 0.357, either 0.36. Now, you assume that, ultimate bearing capacity is on these lines and you know you; so, again you get h g here, you get 0.22.

So, 0.36 minus 0.22 will be the change in the savings, because of the aggregate. So, this is what it is and now that is why, you know, it is because of the you know you are as I just mentioned we are increasing the load from elastic to plastic, because we assume that we provided a a geotextile, which can which cannot allow contamination.

So, contamination is prevented by this geotextile and because of which you can go for little higher loads, loads can be higher. So, in the previous case, it is 0.36 and its 0.22, the difference is so much. So, you also have this number 0.8, which is nothing but without any considering the load repetitions, considering the rut depth, you have this number 0.8. So, 0.8 0.8 minus 0.14 gives you the actual depth of the geotextile. So, you can see that, it is about good savings is there in the with just separation function.

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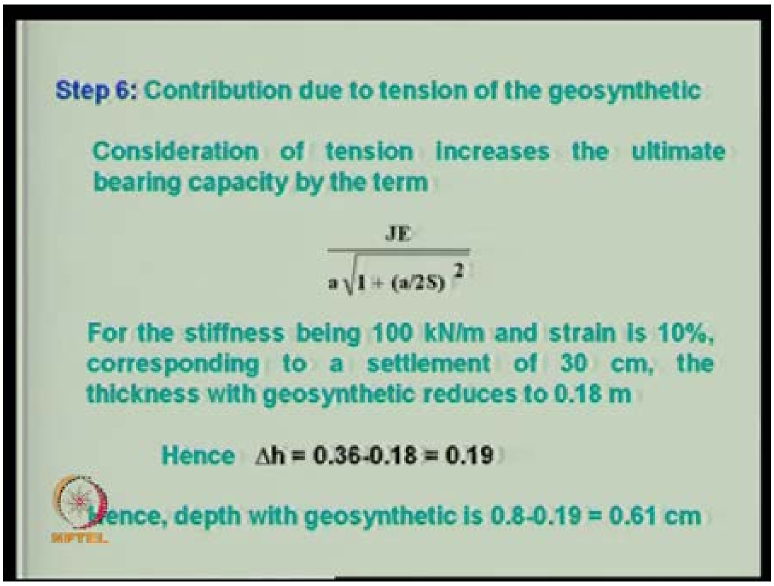

Now, how do you consider the stiffness of the geosynthetic or the reinforcement function? We know that because of this say tension membrane effect, the possibility is that, the load gets reduced and assume that the stiffness is about 100 kilo newton per meter; and the strain is 100, 10 percent and the settlement is about this number, and the thickness with geosynthetic reduces to 0.18; so, 18 centimeters.

So, what I meant was that, in this case, it was previously it was the I will just show you the previously it is about 0.14. And now, in the same thing, you put that you know the thing is this term has to be into that equation; again it reduces to about little extra, instead of 0.3, we have done, what we have done previously was 0.36 minus 0.22, right.

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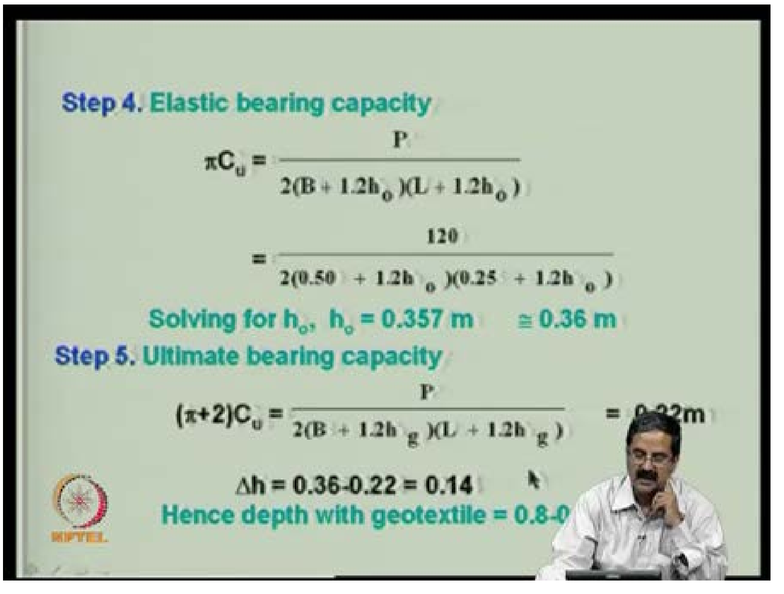

you can just see in the previous step, 0.36 minus 0.22 is what we did, and that leads to a reduction of the final thickness will be 0.66, and this 0.14 is the reduction, because we did like this. now, since the geotextile acts, you know, you can the see the ultimate bearing capacity further increases, right. So, like because of this factor here, like you know, the load is also taken care of by the tension force mobilized like this.

This is a term extra term that you get, and once you substitute all that, you will get a number which is little lesser you know. So, what it means is that, it is a marginal difference is there. In fact, with the depth in the geosynthetics is, it can be instead of instead of earlier, what we had was 0.66, now it is 0.61.

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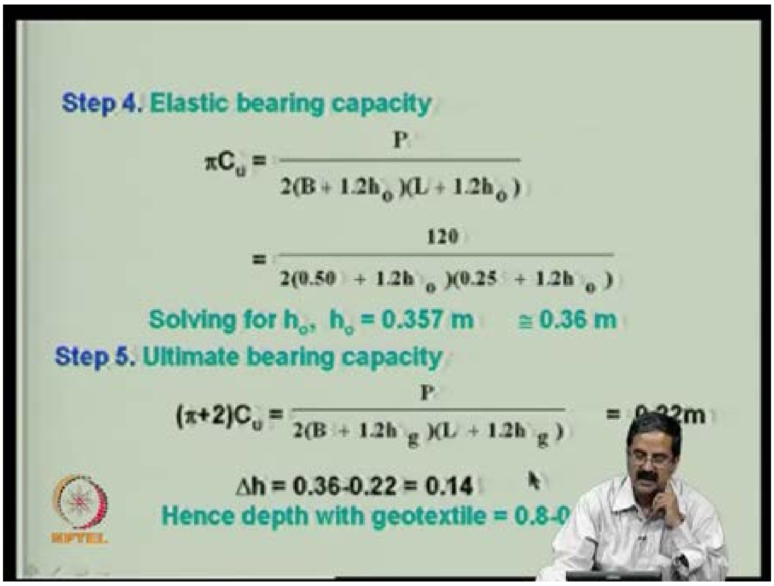

So, if you consider the geosynthetic material, stiffness and the reinforcement, there is a marginal difference, but the separation alone is good enough, particularly in if you are trying to do a village road, you you can just put a separator nothing else; separator is much cheaper, whereas the reinforcement is somewhat expensive; you know, consider that, it is like a may be 3 units in without just as a separator, but it can before as 5 or 6 units, if if you want a good reduction and settlements and all that.

So, it is a good difference is what one can say that, with just separation function alone, one can achieve some significant differences. I would like to tell you one more thing was that, the calculation is a trial and error procedure, what we should do is that, the same you have to put it here the term and then calculate, which value of how this you know you have to do either by trial and error or solving, one can get this and get this, h g value ok. It is possible to do some trial and error procedures and then get this result.

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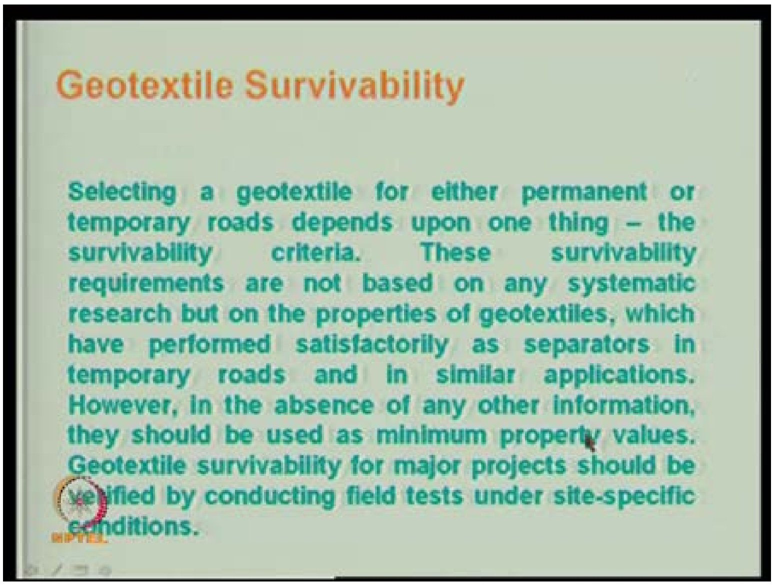

Now, as I just mentioned, survivability of the geotextile, we just discussed, and selecting a geotextile a for either permanent or temporary roads depends on the survivability criteria. The survivability criteria are not based on any systematic research, we should accept that, but is just the properties of the geotextiles which have been, which are performed satisfactorily as separators in temporary roads and similar applications, like we have see in the case of geo, I mean, filters and drainage functions, where a separate may be we have the separate heading survivability criteria.

And they had certain specifications like, it should be the graph strength should be this much, puncture strength should be this much, all that, which which are only, you know, the specifications are drawn in a such a manner, that you do not have a difficulty in installing the field. And they do not get damaged in the field while doing things, that is it. So, if they are able to satisfy that requirement, its fine; you can use it in the as a separator.

So, the geotextiles and their survivability that is already given in some standard, you know, the manufacturing literature it is given, like if you by a geotextile of a particular grade, they will clearly give you that, yeah this is the apparent opening size, this is the like you know, if you want to take the permeability criteria also in pavement design, apparent opening size is required.

And if you just the reinforcement function is required, it is the stiffness is required; and then, separation if you are only talking about survivability criteria, only that what is that, handling stresses, like how much of load it can tak,. like you know, if I just take this load and if a big stone falls on it, it should not get punctured.

So, what is that puncture resistance is that, how many Newton it is or how many what is the force it can take; without getting punctured is what we like to, see, and these are all by trial and error, and then by practical applications and experience. And people have standardized this numbers for different applications, and if you are very particular, one can get that testing done, field test, lab test, all that, for the supplied products. And also in the field also, one can do, what could be a bearing strength or what could be the actual ah load and all that, one can see.

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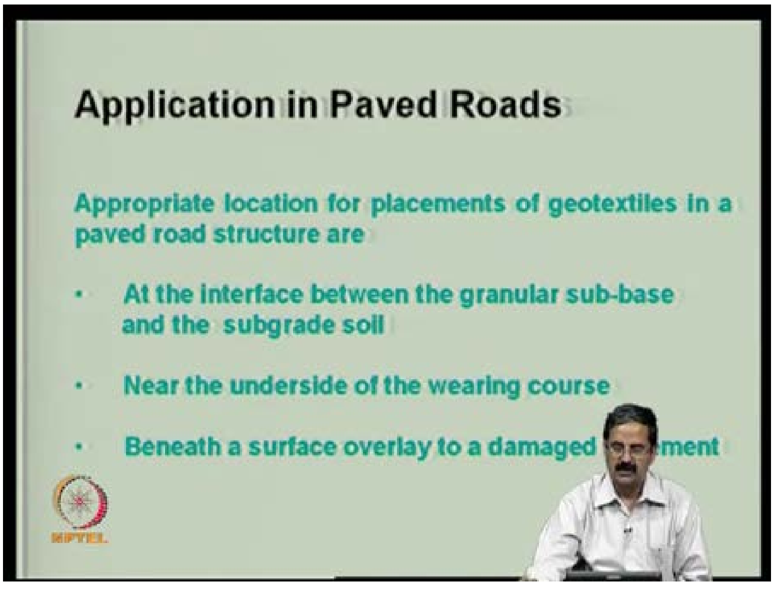

So, I also would like to highlight some more applications. So, the paved, unpaved road is that, where you are able to decrease the thickness of the pavement to some extent by using the concept of separation, and also one can use reinforcement. And if you think that the road drainage is a problem, you can do a filter design; and then, the most important thing is, once you do a paved road, what is next, you make you must make it paved, right; you have to have a wearing course.

How to do that? And do you think that geotextiles are useful here also? One should understand, yes, they are very helpful here also, because I will tell you that they can be used in many places here also, like the appropriate locations are, that like you know, the thing is you have a sub base, first is the sub grade, then sub base and wearing course.

So, at the interface between a granular sub base and sub grade soil, right in the beginning, like where you have a two, first is the sub grade, next to that put a geotextile and then take a sub base. The other thing is below the wearing course of the wearing course also you can keep; beneath the surface overlay to a damaged pavement. So, I will discuss some of these things much more detail in in a separate lecture on paved roads use, and what I want to say is that, all these things are quite, in all these places, they are quite effective.

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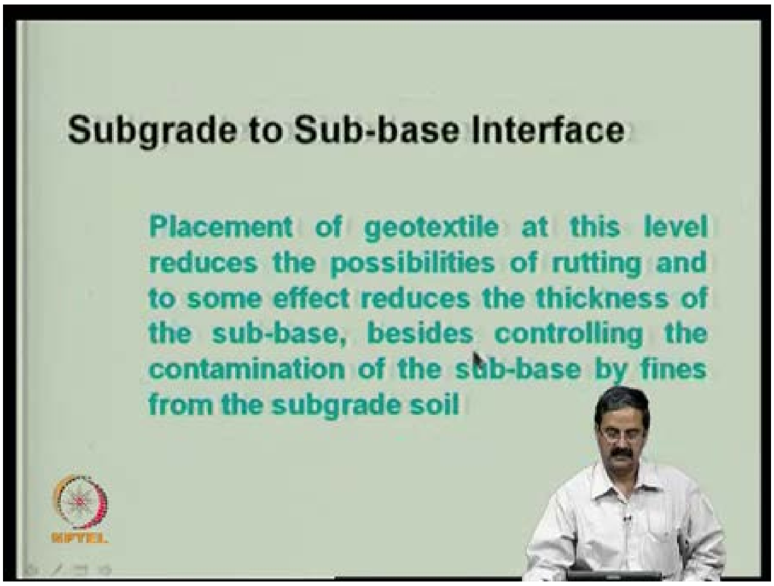

So, if I want to put a sub grade to sub base interface, placing this level, you know, placing the geotextile at this level reduces the possibilities of rutting. And to some extent reduces the thickness of the sub base, besides controlling the contamination sub base, base by fines from the sub grade soil.

What we are doing is that, you know, like what are the methods by which, what are the failure modes of flexible pavement: one is rutting, rutting means that formulation of thick or you know whatever, you know, depressions you call it, that is called rutting.

Then, the fatigue, the fatigue and rutting are the two things; fatigue is because of the load repetitions - number of load repetitions - that you have, and fatigue and rutting are two main criteria's at least in, if you look at pavement design, for flexible pavements, bituminous pavements, both are quite usual, right.

So, if you are able to place that a geotextile, I know the thing is that, rutting occurs at the top most portion, bottom most portion of the it starts in the sub grade actually; you know, you have a sub all that sub base and all that, and close to that, if the if the bends like this, there are tensile strengths are there, then it is likely that it leads to rutting, right.

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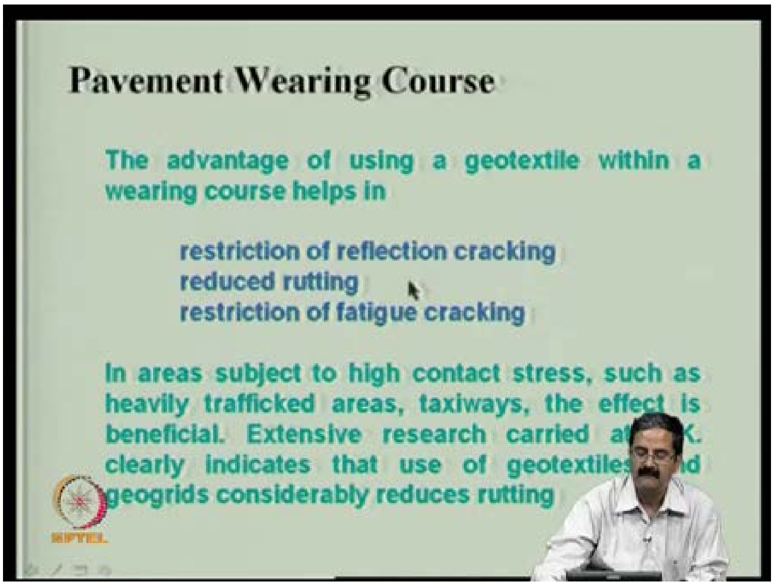

So, you, but then, if you are able to place that little above, the advantage of putting that in a wearing course helps in restriction of reflection cracking, reduced rutting as well, because it takes care of some load and the from the, you know, instead of transferring it somewhere down, it just takes care of some load at the top layer itself.

Restriction of fatigue cracking, you know, because of the alternate or repeated action of loads, the fatigue cracks do develop. And in areas such as high contact stresses or where you have heavily trafficked areas or taxiways, where you know in run ways and all a head fill pavements, the effect is beneficial. In fact, lot of work has been done in U K and other places, where they are able to clearly show that, the use of geotextiles and geogrids considerably reduces rutting.

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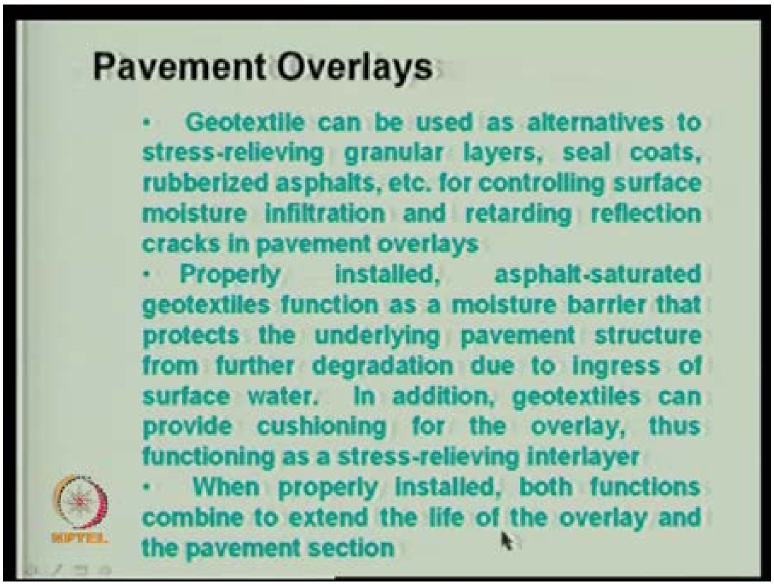

The other important point that we have is that, you know, you have to repair the roads, right, that is called you know overlaying of a pavement. So, geotextiles can be used as alternatives to stress-relieving granular players, like you know, why do put granular layers i, because they take stress right, because of the load dispersion capacity.

So, then, in some cases, the people put seal coats, rubberized asphalts, all, these materials for controlling surface moisture infiltration, retarding reflection cracks and pavement overlays, ok. So, instead of that, one can use a geotextile. So, in pavement overlays or in the pavement rehabilitation, geotextiles are very useful compared to some of this things, like you know, they help in you know normally conventional highway engineers or pavement engineers, they know about this use of granular sub base, you know, they say that you provide higher thickness of the granular base or provide a seal coat or provide rubberized asphalt, which can take care of cracks will not be there or even for controlling moisture.

All that can be avoided by a geo grid textile; a properly installed and asphalt saturated geotextiles also, say sometimes, you can take a geotextile and immerse in bitumen at a very high temperature, it can work as a moisture barrier; you know, geomembrane we have, say geomembrane could be expensive, so what do you do?

Anyhow you are doing a road work, you have a bitumen. In fact, a bitumen is you know actually geomembrane is also from that processing and coal, that tar product, but whatever you know, one can say that, if you want to really work, see that the moisture barrier; it acts as a moisture barrier, you can take geotextile, put dip it in a bitumen and it becomes a moisture barrier.

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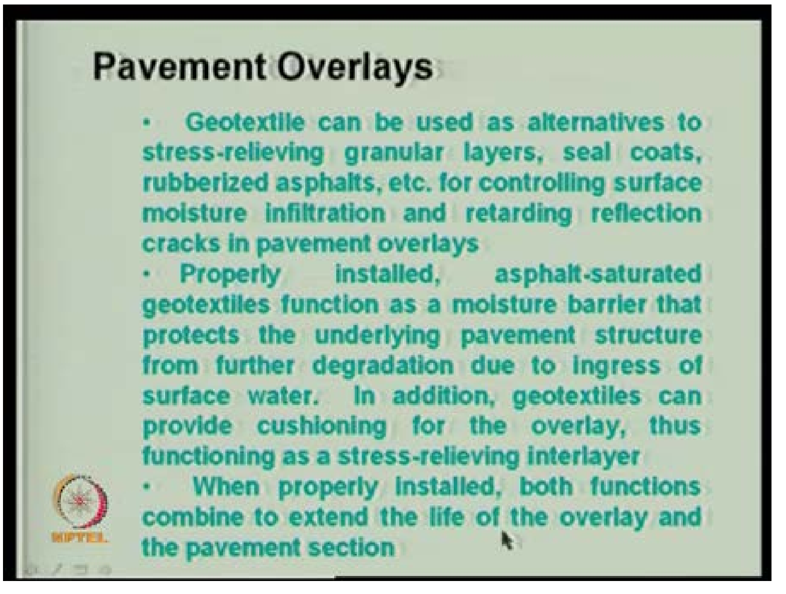

And it helps in you know prevention of ingress of water. In some cases, where the you know you want to avoid the water movement, you can make it as a moisture barrier and see that that is quite effective. So, geotextile, you know, it acts as a stress leaving layer; you know, it is a doubt undoubtedly, it acts as a stress leaving layer, because it can take some load. And when you insert it properly, there is a method of installation, like you know, the way it should be cleaned properly. And there are different types of failure, like a debonding is a quite normal thing that you know delamination.

Because layers they are all constructed in layers, layers come out you know, you see in road work, the layers come out and the possibility is that, if you are able to use geotextiles and you know there was some more products, one can effectively increase a life of the overlay and also the pavement section.

This is a very important thing and they are also cost effective. In fact, I know that, you know, the we have the yelahanka airfield pavement, you know the which is being used for which was being used for a aero shows, even now it is being used.

And they wanted to the you know The thing is that, see, when the flights come and take off, they introduce lot of stresses into the pavement, like you know, the stresses at the top layer are going to be very high; you know, while landing as well as taking off, the stresses are going to be very high, and what they did was that, at the top, they put a very high tensile geogrid, which is called glass grid and it has been very effective.

And you know, the it is so stiff, that is stiffer than actually a conventional geogrid, and its very much required there, because they need to develop that much of tensile force and also must be very stiff. So, like that, the you know people have been, you know, using some of these materials in a very successful manner, in most of the pavement construction, particularly when you are trying to handle the soft soils.

So, with this, I would like to conclude, I would like to say that, the pavement design using geosynthetics is a simple approach, which is given by Giraud and giroud and noiray; and there are lot of advances in the recent times. In fact, what was suggested words for geogrids, but that was in 1978 and 1984 and 1990, even in latest 2004, you have an excellent papers on geogrids, which can be very very useful.

And they are quite, you know, efficient in helpful; the the design methods are very consistent in field applications also, because what is happening is that, you know, many of these failure mechanisms of you know fatigue and rutting are actually, you know, you you observe them in the field, you do not want them actually. You know if you have a big rut formed or lot of cracks and their pavement, may be our design is perfect, like a CBI design is nice or some other design is correct, but they will not tell you they will not be able to explain why these failures are occurring.

So, that is a one design issue, but what way the best way is to avoid that problems. So, you know, so you put some nice appropriate geogrid and it improves the quality of the design is ok and quality of life is also ok, service is also ok, all of these serviceability performance, the pavement thickness reduction, all things are possible.

In fact, in India Indian roads, congress has some specifications, and in many places, people have been using in road design extensively, and like lot of field trials have been conducted. And even in particularly, this is one thing in soft soils, see for example, many people, they do they have done lot of field experiments, where the soil is so soft; you have one soft. So, you know the thickness and then you provide as per conventional design, then you come out with some other design using geosynthetic, like a geogrids.

Then, you can go for a geotextile, all of these and they did lot of field test field test; in this sense, in accessing the pavement performance, there are some many equipment, which can access the field performance; particularly in the in the case of roads, like using falling weight deflectometer, using roughness measurements, like you know, profilometers, and all that, there are so many equipments in the pavement engineering, that one can use and link it to its performance. So, with this, I will conclude.

Thank you.