Geosynthetics and ReinForced Soil Structures

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Lecture - 32
Geosynthetics in Flexible Pavements – II

Good afternoon students, in the previous class we have seen the design of the pavements with geosynthetics, and let us continue the same topic in today's lecture.

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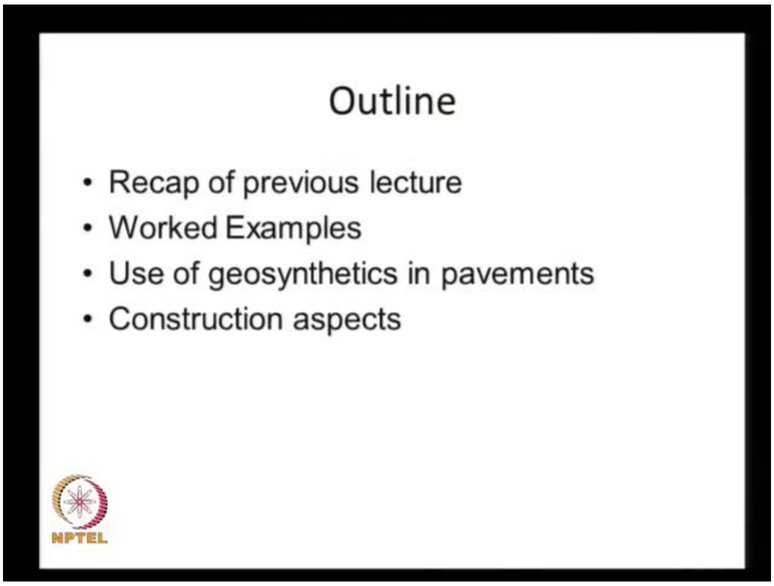

A brief outline of today's lecture is, we will have a recap of the previous lecture. Then we will work out some numerical examples to illustrate whatever we have discussed in previous class, and we will see how the geosynthetics are applied in pavements for different to overcome different problem. Then we will briefly look at some construction aspects.

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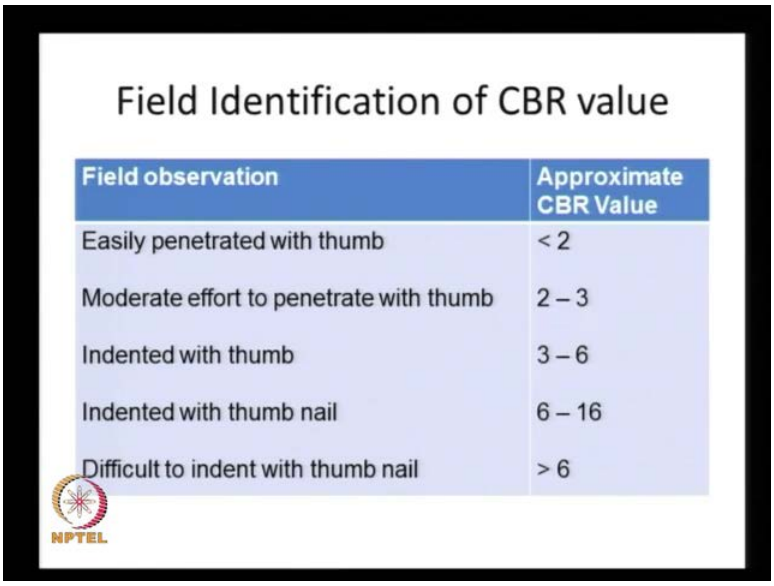

We have seen in the previous class, that the entire design of flexible pavements is based on the on the California bearing ratio or CBR of the sub grade. This particular table gives some guidelines and how to interpret some filed observations for the CBR values, because many times we go to the field, we may not even have time to collect a soil sample bring it to the lab and do the testing. It is just as an approximate guide, if we collect soil sample in a tube and if you are able to easily penetrate our thumb, we can say that the CBR of that particular soil is less than 2. If you have to exert some moderate pressure to penetrate our thumb, the CBR value could be anywhere in the range of 2 to 3.

When we try to penetrate our thumb, we are able to make only a small indentation, the CBR value could be anywhere from 3 to 6. Let us say we are not able to indent with the thumb, but using the nail if you are able to indent it the CBR value could be anywhere from 6 to 16. If you are able to indent even with a thumb nail, this CBR value could be greater than 16. So, this table gives us some way of identifying the CBR value of the soil that we come across in site.

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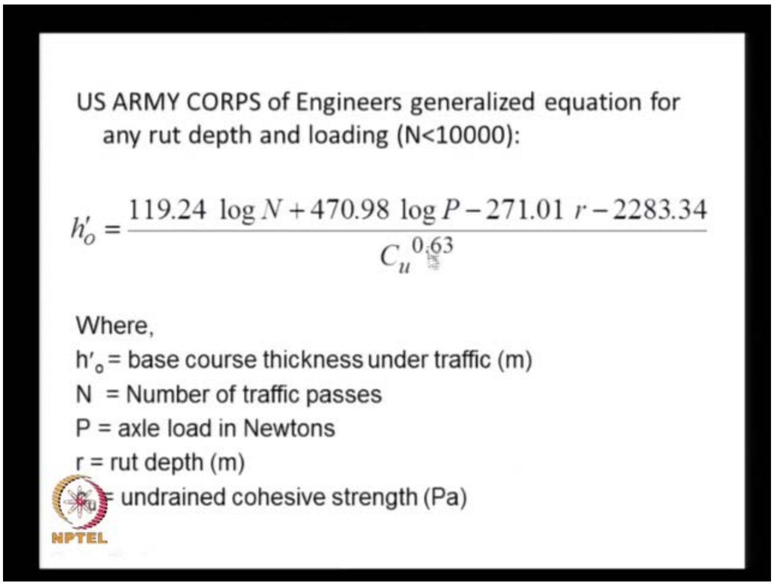

This particular formula we have seen in the previous class, this was adopted by Zero du Noire based on the data from US army core of engineers. This particular formula is valid only for the number of passes less than 10,000 and this is a generalized formula because we can consider any axle load P and the any rut depth r, and then the soil cohesive strength this u undrained cohesive strength. The previous formulas, that we have seen in the earlier class that are very particular for a standard axle load of 80 kilo Newtons, then rut depth of 75 millimeters.

Here, it is not prime is the base course thickness under given number of traffic repetitions, this is in meters and capital N is the number of traffic passes. P is the axle load in Newton's, r is the rut depth in meters and the C u is the undrained cohesive strength in Pascal's. We have seen in the previous class that approximately one CBR is equal to 30 kilo Pascal's or 30,000 Pascal's and the C u is approximately equal to the CBR value times 30 in terms of kilo Pascal's.

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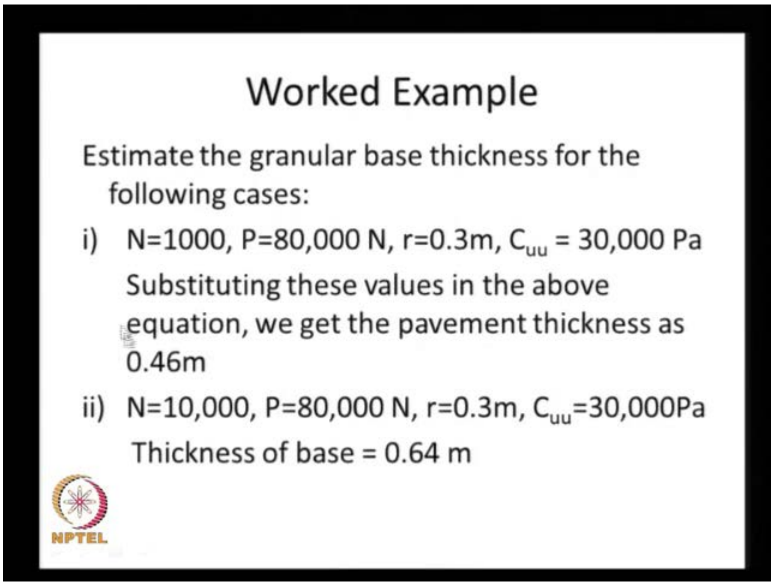

Now, let us look at some numerical example and how to apply this equation, because it is a combined equation that gives us the influence of the number of traffic passes n, and then the axle loads P the rut depth r and this C u. The effect of all these factors on the pavements thickness and let us say that we have a axle load of a 80,000 Newton's and allowable rut depth of 0.3 meters, and the C u is 30 kilo Pascal or 30,000 Pascal's. The number of passes 1000 and 10,000 and in the case of 1000 passes, if you substitute all the values the pavements thickness comes out as 0.46. Let us say that in the second example, we keep all other parameters the same except that we increase the number of passes to 10,000. Now, our base thickness increases to 0.64 meters, earlier it was 0.46 meters.

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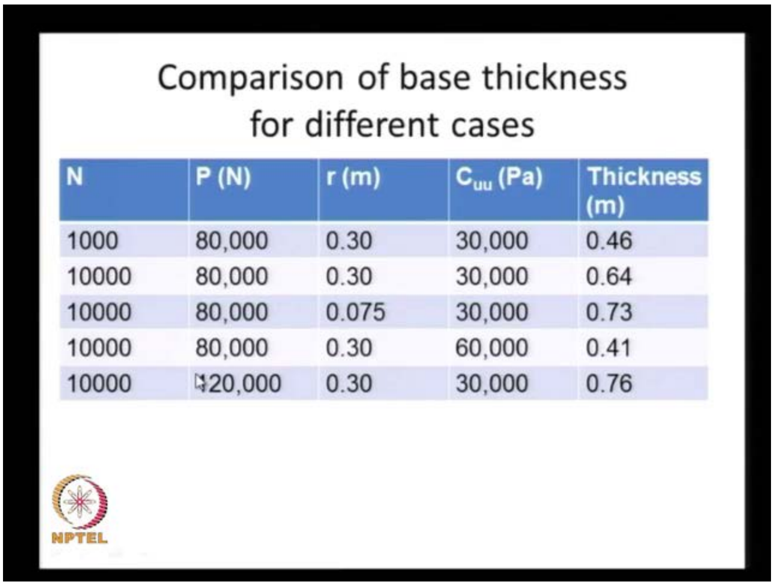

Comparison of base thickness for different cases

N	P (N)	r (m)	C_{uu} (Pa)	Thickness (m)
1000	80,000	0.30	30,000	0.46
10000	80,000	0.30	30,000	0.64
10000	80,000	0.075	30,000	0.73
10000	80,000	0.30	60,000	0.41
10000	120,000	0.30	30,000	0.76

Now, let us look at the different combinations and directly compare one against the other. Let us take the very low number of passes 1000 axle load of 80,000 Newton's, rut depth of 0.3 and the C u of 30 kilo Pascal or 30,000 Pascal's, the thickness required is 0.46. When we increase the number of passes to 10,000, the rut depth, sorry the thickness of the pavements increases to 0.64. Let us keep the same number of passes as 10,000 and the axle load of 80,000, but decrease the rut depth, allowable rut depth to 0.075 and the C u of 30,000 Pascal's. The thickness of the pavement increases to 0.73, so that means that if we have a lower tolerable rut depth, we need to provide thicker granular base.

So, our combined stiffness is higher that results in lesser rut and the influence of the C u increase of Cu to 60,000 Pascal's is to reduce the thickness. Now, the thickness has reduced to 0.41 from earlier 0.64 and if you increase the axle load to 1,20,000 Newton's, and while all other parameters are the same and the thickness of the pavement increases to 0.76 meters. So, this particular equation that we have is actually it is adopted by Zero du Noire from the earlier publications of the US army core of engineers, to express the effect of all the parameters on the thickness of this pavement. This particular equation is only valid for unreinforced pavements.

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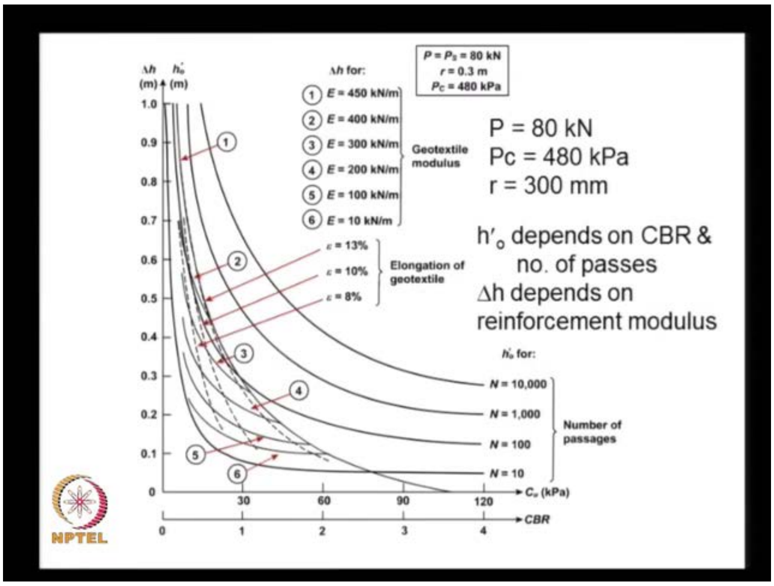

For the case of geosynthetic reinforcement, Zero and Noire they have worked out the solutions and given the thickness in terms of the CBR value, and the x axis, and here we have two quantities h naught prime. This is thickness of the unreinforced pavement for the case of standard axle load of 80 kilo Newton’s and the tire pressure of 480 kilo Pascal. A rut depth of 300 millimeters and here the x naught is only dependent on the CBR value of the sub grade.

Then the number of load passes are worked out in terms of 10, 100. 1000, 10,000, you see that everything is in terms of log scale. So, if you know the CBR value or the undrianed cohesive strength of the soil, we can directly read off the thickness of the unreinforcement pavement directly from this graph. Then the other quantity is the delta h, that is the possible reduction in the thickness of the pavement, because of the placement of geosynthetic layer and the solutions are given for different secret modulus values. The E of 10 kilo Newton, 100 kilo Newton per meter, 200, 300, 400, 450. So, this directly we can read off the CBR value against this modulus, so we have totally six graphs and we can directly read off this delta h.

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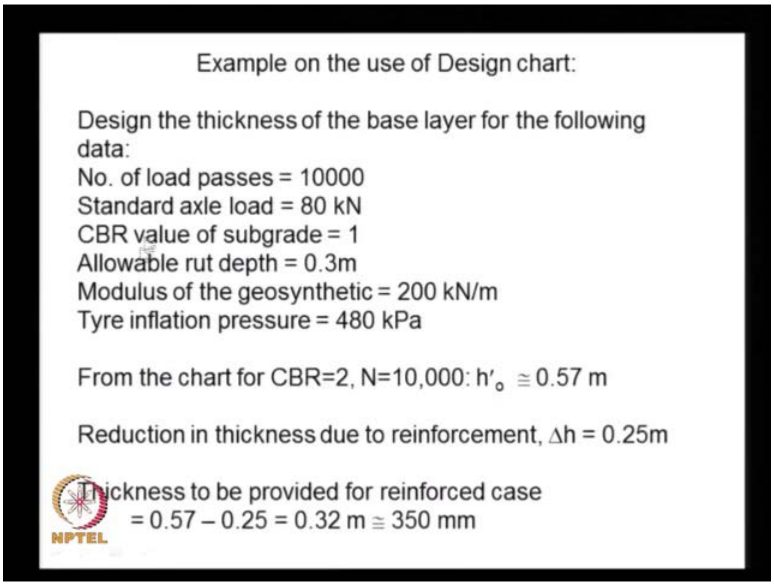

Now, let us look at one small design example, let say that our number of load passes of the number of load repetitions is 10,000 and the standard axle load is 80 kilo Newton's. Let us say that our CBR value of the sub grade is 1 and allowable rut depth is 0.3 meters and modulus of the geosynthetic is given as 200 kilo Newton per meter. The tire inflation pressure is 480 and form the chart for a CBR of one sorry this should be one and n of ten thousand the thickness of the pavement for the unreinforced case comes out approximately 0.57. So this one and rep repetitions is ten thousand so directly we can read off and it comes about 0.57 and then the reduction in the thickness because of the placement of the reinforcement for a CBR of 1 and modulus of 200. This delta h comes to approximately 0.25, so let us see this CBR of 1 is here and this, sorry this core, this fourth graph, sorry this fourth graph is corresponding to E of 200.

So, this comes out about approximately 0.25 and so we can say that because of the provision of the reinforcement, we can reduce the thickness of the pavements by 250millimeters. So, the thickness of the granular base that is to be provided is only now reduced to 350 millimeters form the earlier 570 millimeters. So, it is a substantial saving because this not only decreases the quantity of the natural materials, but also decreases our construction time because we need to bring in this much lesser materials. So, it is faster and then the carbon footprint of the construction also reduces because is we need to bring in any material natural material. We need to spend in terms of what the number of lorry passes and other things, so this is this charts that we have they are extremely useful.

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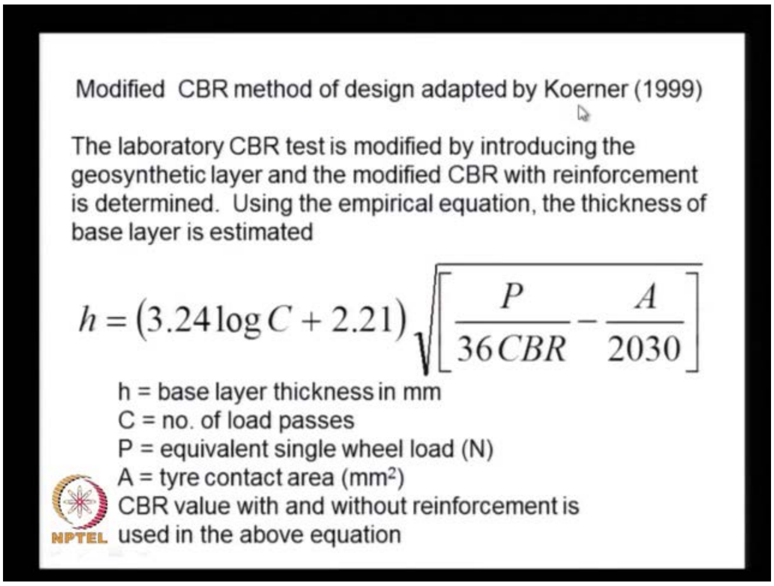

The Koerner in 1999, he has proposed another method for incorporating the effect of reinforcement by taking some empirical equations that was published by the US army core of engineers. He called it as the CBR method of design and here the h is the base layer thickness. This is related to the number of load passes and other factors like this 3.24 log C where C is number of load passes plus 2.21 multiplied by the quantity in square root P by 36 CBR. Here, P is equivalent single wheel load and the CBR value either for unreinforced soil or reinforced soil and A is the tire contact area divided by 2030.

This is the CBR that we use, is either the CBR of the unreinforced sub grade soil or the reinforcement with reinforcement. We can perform a CBR test, a modified CBR test by introducing a layer of geosynthetic at the interface between the aggregate and then our soil and do the normal CBR test and interpret for the increase on CBR value. The units for all these quantities the H is in millimeters the P is in equivalent single wheel load that is in Newton’s that tire contact area is millimeter square and the CBR values in terms of percent, either 1 percent, 12 percent, 23 percent and so on.

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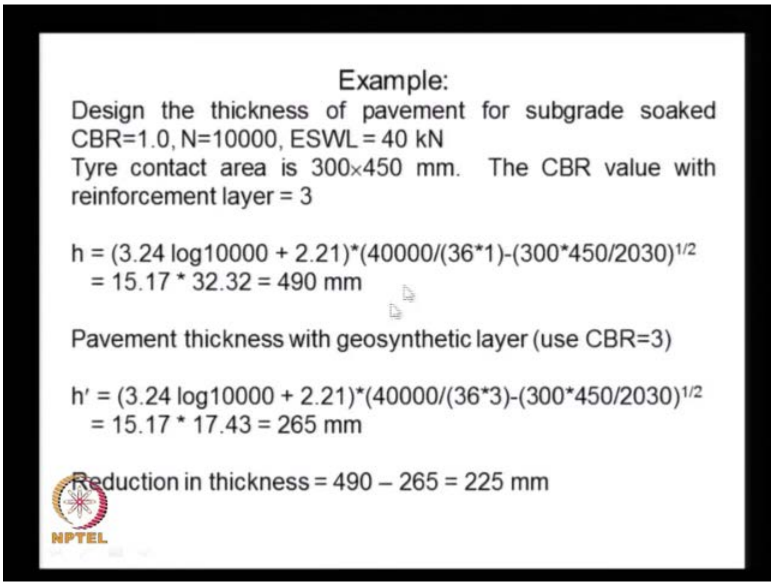

Let us look at simple example design, the thickness of pavement for a soaked sub grade CBR value of 1 and number of load repetitions is 10,000 and the equivalent wheel load is 40 kilo Newton's and the tire contact area is 300 by four 50 millimeters. The CBR value from the modified test by introducing the reinforcement layer is 3. Now, we can substitute all that values in this equation for hips that is 3.24 times log of 10,000 plus 2.21 multiplied by 40,000. This is the wheel load in Newton's divided by 36 times CBR, that is 36 times 1 minus 300 times 450 that is the tire contact area divided by twenty 2030.

This whole quantity to the power of half and this thickness comes 490 millimeters and now let us estimate the same thickness for the case of reinforcement. The CBR value is 3 when we introduce this layer of reinforcement and this explain comes to 265 millimeters. In other words, the reduction in the thickness is 225 millimeters, so it is a substantial reduction in the thickness. So, by either using this modified equation or this design chart; we can estimate the thickness of the pavement for both unreinforced case and for the reinforced case.

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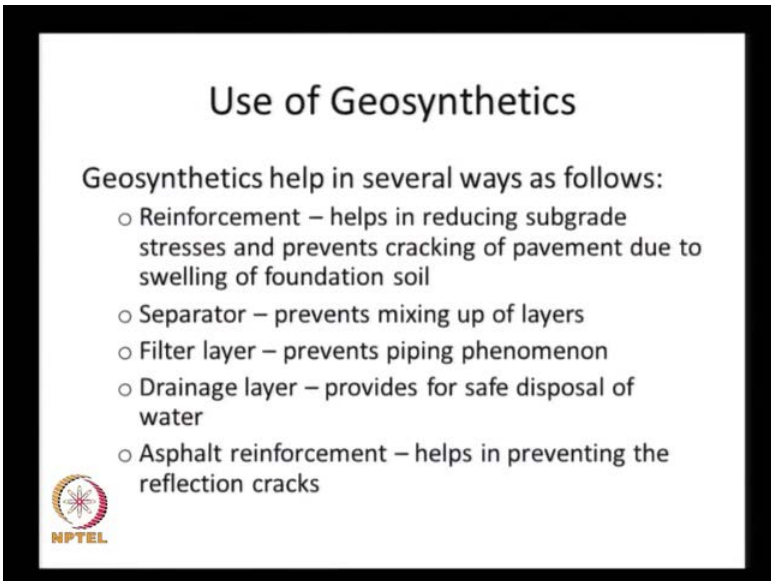

So, let us see how we can employ the geosynthetics for improving the longevity of the pavements and reducing the thickness and also making them durable for a longer time. So, these geosynthetics they help us in several ways in the form of reinforcement. When we use a geosynthetic as a reinforcement layer, it helps in reducing the sub grade stresses and prevents the cracking of pavement and due to the swelling of foundation soil.

I will show you some examples later on, in this lecture illustrate how we can utilize the reinforcement not only in the case of soft sub grade, but also in the case of stiff sub grades where the soil is subjected to swelling or the volume changes. We can use a geosynthetic as a separator that prevents inter mixing of the materials in different layers and as a filter layer to prevent piping phenomenon and as a drainage layer to provide for safe disposal of water. Whatever enters our pavement and as an asphalt reinforcement layer or as a paver reinforcement layer it helps in preventing the reflection cracks.

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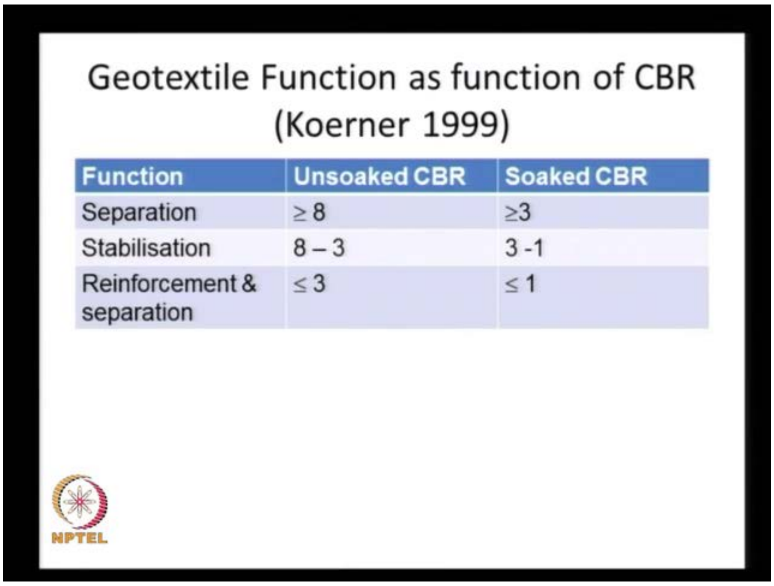

Koerner in 1999 impregnation his text book he has very nicely summarized the function of different geosynthetics based on the CBR values. So, when the soaked CBR of the sub grade soil is greater than 3, we need a geosynthetic or a geotextile only as a separator. You may not require much of reinforcement, function based this strength is sufficient when 3. When the soaked CBR is in the range of 3 to 1, we need to use the geosynthetic not only as a separator, but also as a stabilizing unit or A as a reinforcement layer. For extremely soft soils with CBR of less than 1, the soaked CBR of less than 1, we need both functions as reinforcement or also as a separator.

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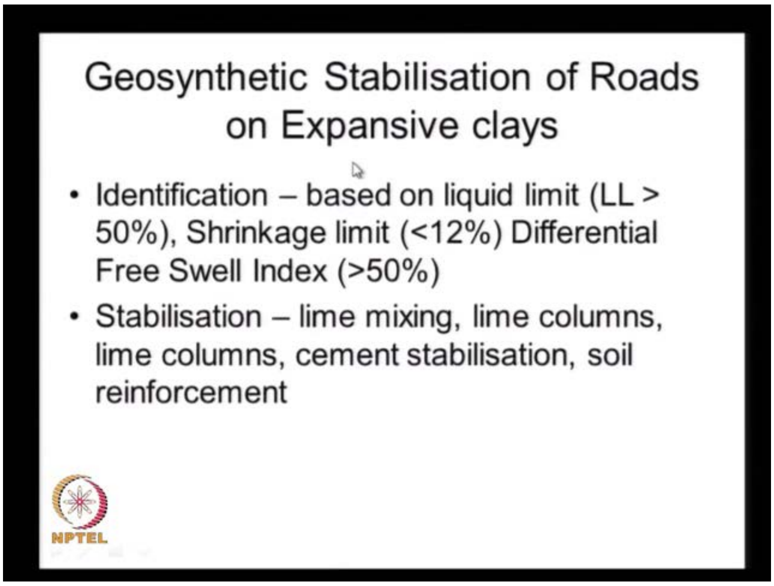

Now, let us see how we can employ the geosynthetics for stabilizing roads on expansive clays. How do we identify what is an expansive clay? So, we can identify them based on the liquid limit, whenever we have a liquid limit of greater than 50 percent, we classify that soil as clay of high plasticity. We can expect the problems not only because of swelling during the winter season or during the rainy season and shrinkage during the dry season. Apart from the liquid limit, the shrinkage limit of less than 12 percent also indicates the swelling nature of the soil and the other quantity that we have is the differential free swell index. Anything more than 50 percent can be classified as a highly problematic soil that may swell or shrink.

What are the different techniques that we have for stabilizing these soils? Traditionally the lime mixing directly is mixing the lime with the sub grade soil or by installation of lime columns or cement stabilization. We can use this cement to bind the soil particles together so that our swelling tendency is reduced or we can use soil reinforcement or that is by providing some reinforcement layer we can suppress the swelling tendency.

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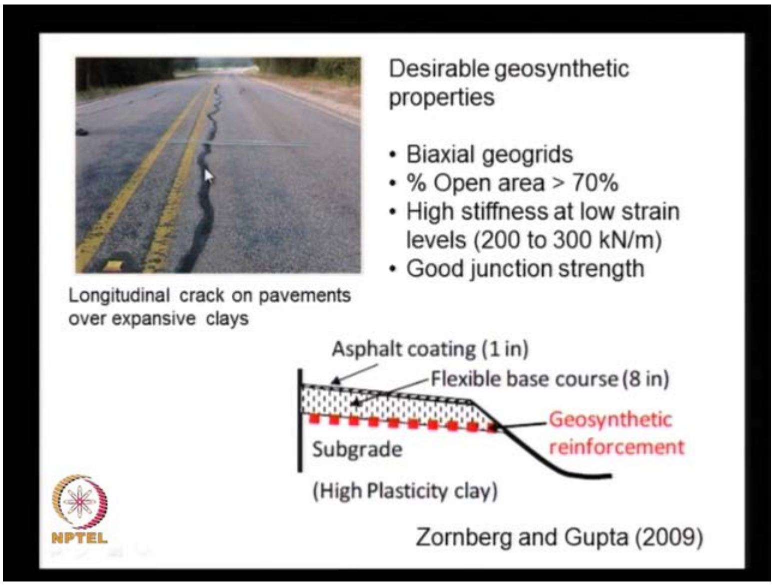

So, what happens when you have the swelling of this soil? This is what happens, the longitudinal crack in the pavements over constructed over expansive over clays. You see this longitudinal crack is actually very wide, this is happening at the center of the road and also at the edges. We can stabilize this type of soil by using suitable biaxial type geogrids, the biaxial geogrid as we know these are the geogrids that have significant tensile strength in two directions. In both the directions longitudinal direction and also in the transverse direction and for this geogrid to have a good interaction with the soil the percent open area should be greater than 70 percent.

These geogrids they should be able to develop high enough tensile loads at a low enough strain. This means that their modulus should be in the range of 200 to 300 kilo Newtons per meter or higher. They should also have good junction strength because when the soil is trying to swell it subjects the geogrid to very large tensile stresses and if the junction is not strong enough the geosynthetic or the geogrid might rupture at the junctions.

This is how we employ a geosynthetic let us say that we have a highly plastic clay soil as a sub grade and we have our base course flexible base course. Below this, we can provide a geosynthetic layer and of course, on top our base course we provide an asphalt coating. This particular material is from the paper that was published by professor Zornberg and his student Gupta in 2009 at the international soil mechanics conference.

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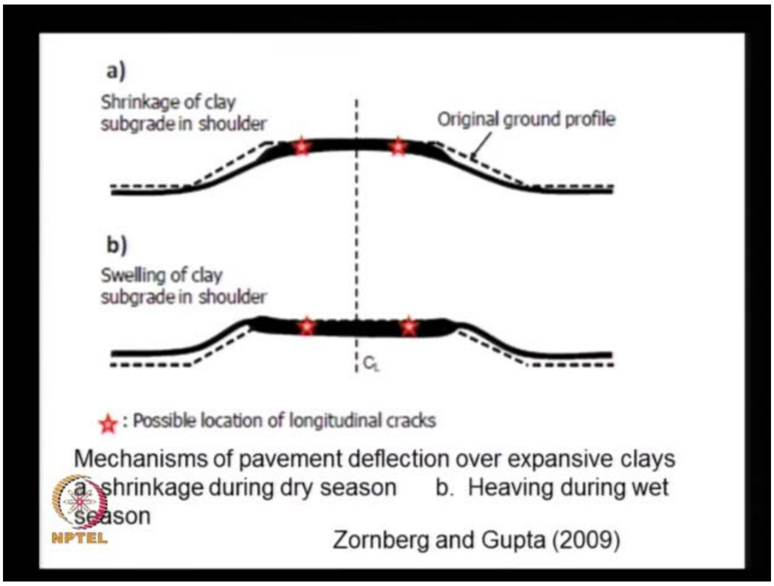

The mechanism that they have proposed is like this, so two cases that is when the embankment strings during the dry season and when the embankment swells. So, this is what happens when the embankment soil shrinks the volume reduces, so originally our embankment, road embankment is shown by these dotted lines like this and because of the shrinkage our volume reduces.

The new configurations of the embankment like this and the likely locations of cracks are shown here or the reverse may happen during the rainy season. There is a volume expansion so here the dotted line is the original configuration and the solid line is the new configuration after the swelling. Once again we can have the tension cracks at these locations, so these provide a reinforcement that can bind the soil together we may have or we could have a good performance.

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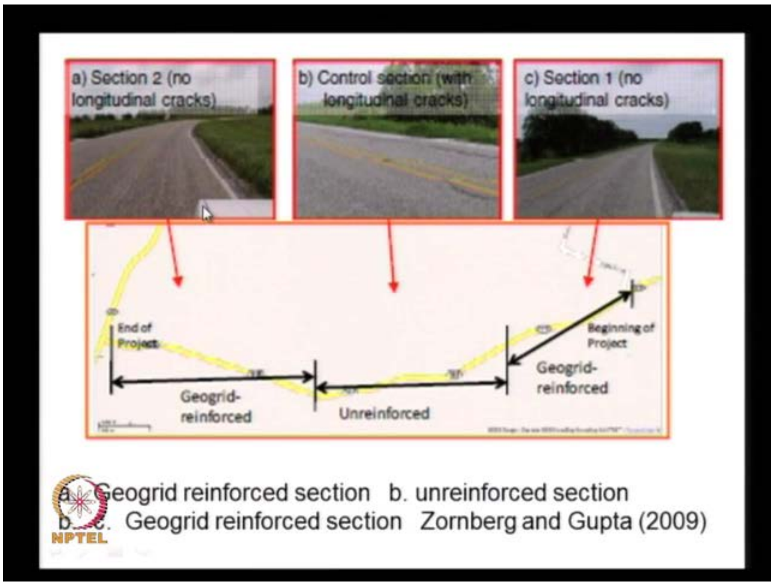

In this paper Zornberg and Gupta, they have presented the data and some field work that they have done in Texas. So, they have treated soil over length of almost 3 kilo meters, they have divided the stretch of the road into three sections. One section is actually section one with reinforcement and then section two with another type of reinforcement then there is a middle section without any reinforcement.

So, wherever they have provided the reinforcement they did not find any longitudinal cracks and where there was no reinforcement they have provided they have seen the cracks. This means that the reinforcement that is provided is able to suppress the volume changes tendencies of this soil and keep the integrity of the pavement nicely. In fact, they have seen the effect of the junction strength of the geogrids they have tested, with two types of geogrids, both having different strengths. So, they have seen that a geosynthetic having a higher strength but having low junction strength it has shown some distress because the ribs have opened out at the junctions. So, overall their conclusion is that the use of a geogrids is suitable solution to get a good performance of pavements in the case of expansive soils.

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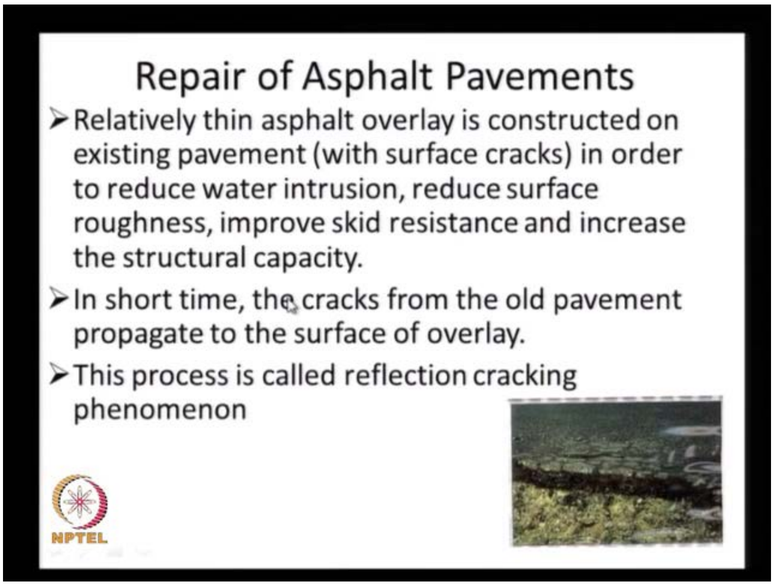

Let us look at another application that is in the case of repair of flexible roads is; actually this is what happens. Let us say that we have a road and the top surface after certain period of service it cracks up and we place a new asphalt layer and that also ends up with cracks this is what happens. So, we provide relatively thin asphalt overlay on the existing pavements that may have some surface cracks in order to reduce water intrusion into the pavement and reduce the surface roughness and improve skid resistance and increase the structural capacity.

This is frequently done as part of the maintenance and when we are repairing sometimes these old cracks they may be filled or they may not be filled. Sometimes, we notice that within a short time the cracks from the old pavement they propagate to the surface and the new pavement also undergoes failure. This process of the cracks spreading from the old pavement to the new overlay is called as the reflection cracking and it is a use very usual phenomenon that we see in the most of the flexible pavements. As a result of the reflection cracking phenomenon whatever overlay that we provide it ends up in failure and how do we increase the longevity of this asphalt pavement that we provide.

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This can be easily done by using geosynthetics and here we see an example of an application of a paver block, sorry the paver fabric on the highway from Mumbai to Ahmedabad. This is a typical crack pattern that we see on the roads because of several reasons and on the right hand side you see the pavement and this portion is treated with overlay fabric. This portion is not treated when they have reconstructed this new pavement and within a short time the portion that is not treated has ended up with cracks whereas, the portion that was treated it is perfectly fine it is able to sustain its integrity. So, that means that if you are able to use an overlay fabric we can increase the longevity of our pavements and this is how it works.

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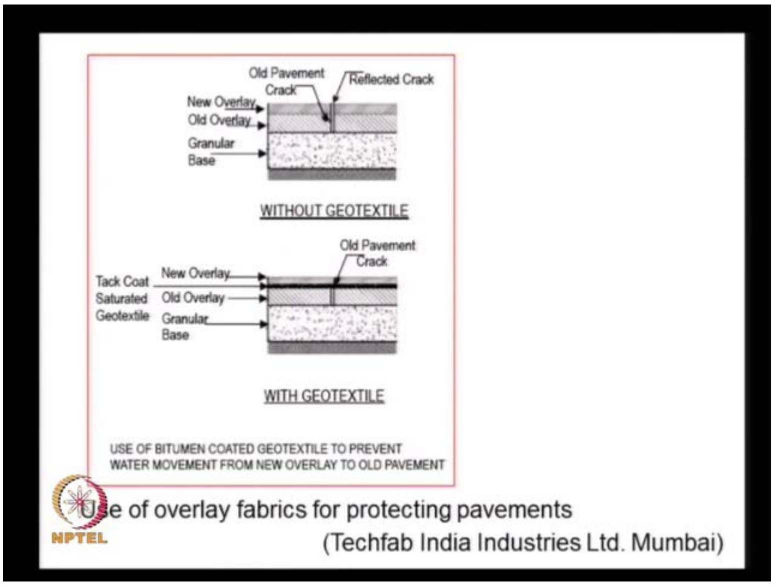

Let us say that this is our granular base and we have the old overlay or old pavement which has a crack and then on top of that we pore new asphalt to repair this cracks and in our time this crack just simply propagates resulting in the in the failure of the pavement. This is without any overlay fabric, now let us say that at the interface of the old pavement and the new pavement, we introduce some abstraction in the form of geotextile or glass grid or we have several varieties of products that we can use.

In this particular example, we see that they have used a geotextile that is saturated with tack coat and in one of the early lectures; we have seen the property of the geotextiles that have binding with asphalt. This particular one, this geotextile used is bitumen coated geotextile to prevent water movement. Also it prevents the surface cracks from propagating and this abstraction that we provide. It confuses the crack and it does not have the continuity to propagate.

So, it requires much longer load repetitions before this crack propagates into the new overlay and that means that our repaired pavement can function for a longer duration without failing. Another manner in which the performance increases is we can cut off the infliction of the surface run off and that is one important factor that needs to be considered whenever we provide this overlay fabric. The water is the culprit that causes failure in most of the soil structures.

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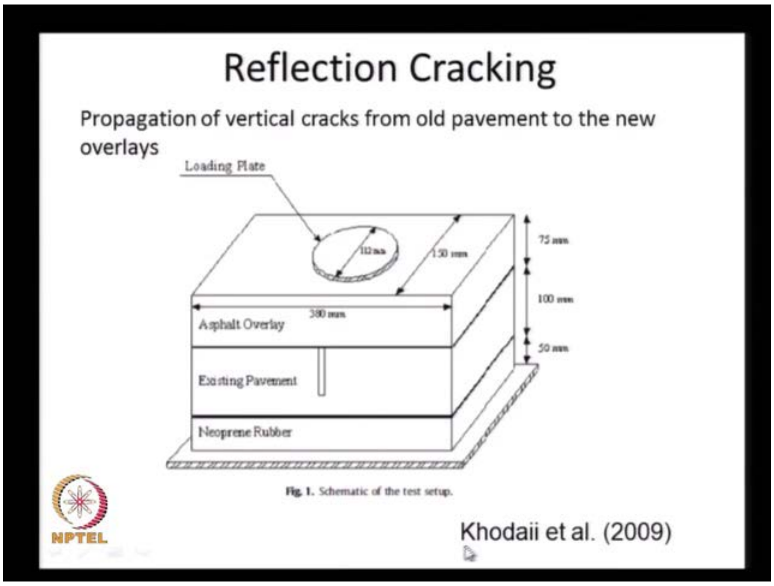

In 2009 Khodaii et al they have published a very nice paper summarizing the laboratory test results from their experiments. They have done some lab laboratory test by giving asphalt overlays that are reinforced with geogrid reinforcement and purposely they have given a preexisting track of different widths. They have rested this on top of a neoprene rubber layer to stimulate our flexible base and they have applied repeated loads to cause the failure.

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This is how it is their experimental set up and they have used two types of old pavements. One is a concrete block and the other is an asphalt pavement and in this old pavement they have given a cut. Then they have provided this overlay and with reinforcement or without reinforcement. They have subjected this system to repeated loads with a pressure of 600 kilo Pascal, loading this 690 kilo Pascal's corresponds to standard loading that we have under standard axle load and standard tire pressures.

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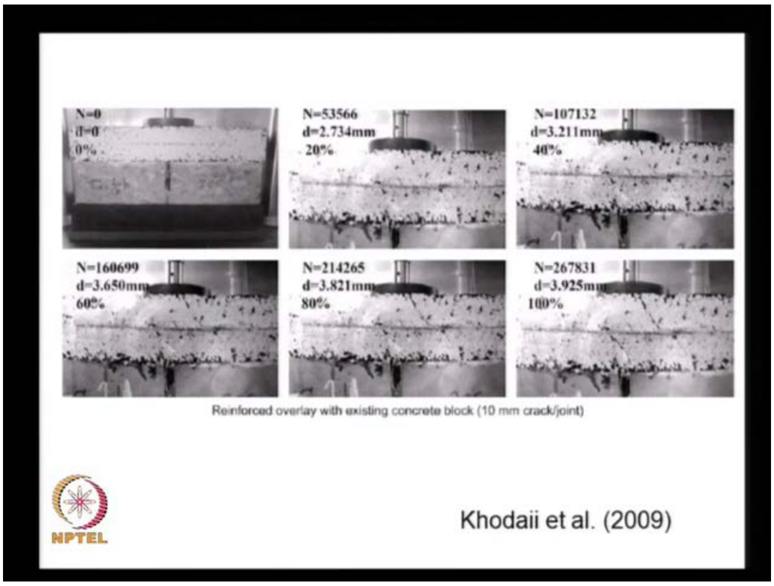

So, the result is something like this particular result is for the reinforced case over existing concrete block. This is the concrete block and this is the start of the test when N is 0 and this is the crack that is there and at 20 percent of the fetid life is absolutely no cracks and 40 percent no cracks, 60 percent no cracks and then finally, 100 percent there are some cracks. This crack has propagated after 2,77,830 cycles of loading at a deflection of 3.9 millimeters.

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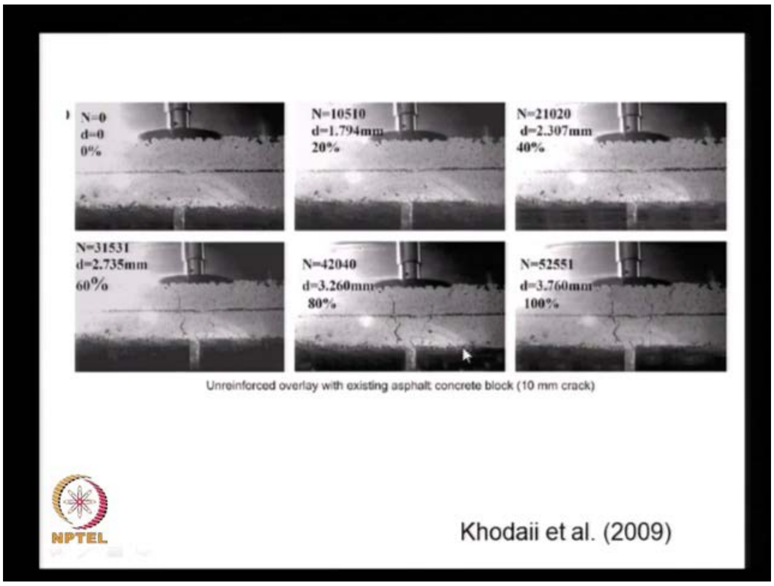

If we compare, the same thing for the unreinforced case is exactly the same, both are exactly similar except that in the previous case we have given a reinforcement layer. Here it is not given and within about 52,000 cycles the entire system has failed, we can see right at about 21,000 cycles there is a small crack that is initiated. It is reflected from the bottom on old pavement and at 31,000, we can clearly see and at 42,000 we can clearly see two of these cracks and at 52,000 this cracks are fully formed. At that stage the test is stopped whereas here even at 2,00,000 cycles the crack has not reached to the top only at about 2,67,000 cycles the crack has reached the top.

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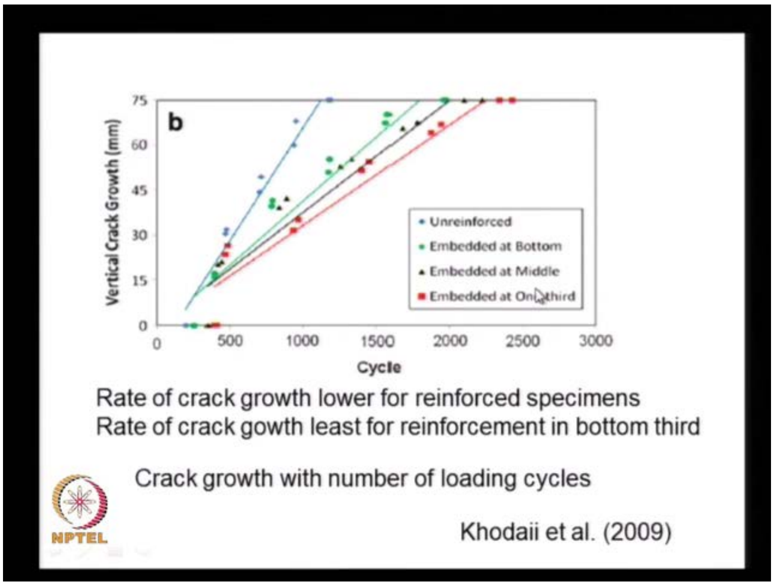

This is how the data is looks like, on the x axis we have the number of cycles and then the y axis, we have the vertical crack growth and when there is no reinforcement immediately the crack propagates. With reinforcement at different levels, the crack propagates at a slower rate that is they have tested with by placing the reinforcement at three locations, at the bottom, then at middle of the overlay and then at bottom one third.

They have seen the best performance when the reinforcement is placed at the bottom one third is actually what happens is when it is placed at the interface of the old pavements. The new and the new overlay of the result was not very good, that means that there is a separation that is taking place between the old and the new pavement. If it is placed at mid height, it is almost in the compression zone like we know that when we have a simply supported beam the bottom fiber is subjected to tension and the top fiber is com subjected to compression.

Exactly at the neutral axis, the strain is 0 and unless we provide reinforcement where there is a significant tensile strain we may not get much of a benefit and that is what they have seen. So, when the reinforcement is placed at the bottom of the overlay there is not much of benefit because there is a separation whereas at mid height there is not too much benefit. This is more closer towards the neutral axis, but then if it is provided at one third of the of the base height, it has the maximum benefit that means that the reinforcement is able to hold the tensile cracks together, so the pavements performance better.

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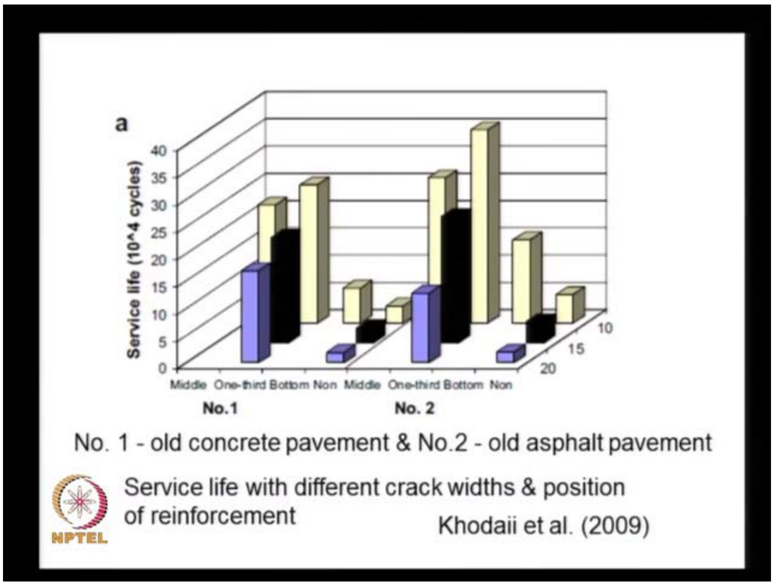

Here, we see the data and a form of a dark chart this data is for three different crack widths 10 millimeters, 15 millimeters and 20 millimeters and obviously with 20 mm initial crack width the number of cycles to failure is lesser. With 10 mm crack width, the number of cycles high and there are two types of test that is number one is old concrete pavements and number two is the asphalt pavement the old one. When the reinforcement is provided at the one third depths there is good improvement and bottom one third is the best performance. When there is no reinforcement the number of cycles to failure is very low and when it is at bottom also, the reinforcement benefit is low.

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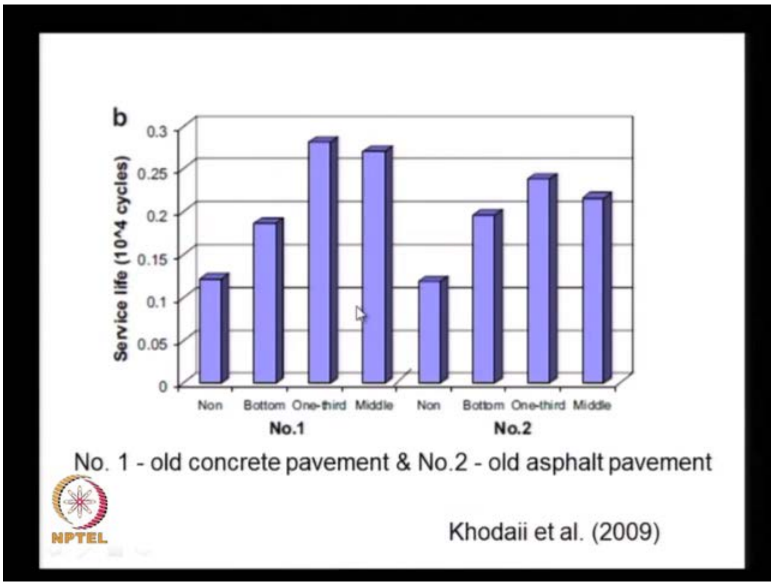

The same data published in a in a slightly different form, there is no reinforcement and when the reinforcement is provided with the bottom and one third and that mid height. So, when the reinforcement is provided at one third height from the bottom it has the maximum benefit, so this we see that when we place a reinforcement at bottom one third of the new overlay, we can increase the longevity of the pavement.

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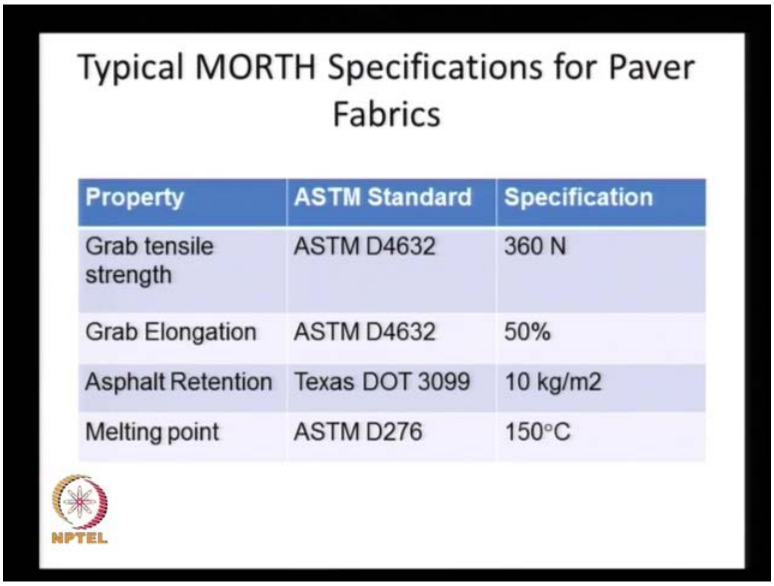

Typical MORTH Specifications for Paver Fabrics

Property	ASTM Standard	Specification
Grab tensile strength	ASTM D4632	360 N
Grab Elongation	ASTM D4632	50%
Asphalt Retention	Texas DOT 3099	10 kg/m2
Melting point	ASTM D276	150°C

These are some of the MORTH specifications for paver fabrics this is the ministry of road transport and highways. The graph tensile strength should be of the order of 360 Newton's. The elongation, grab elongation is 50 percent, then asphalt retention should be 10 kg per square meter and the melting point should be greater than 150 degree centigrade. The asphalt is placed at a very high temperature and our geosynthetic it should be stable at that temperature.

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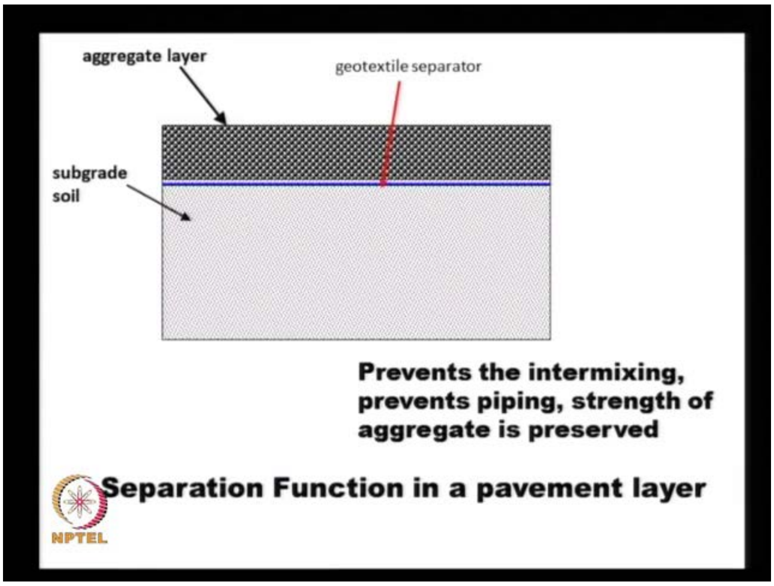

The separation function is something like this: let us say that we have a soft sub grade we have this aggregate layer and unless we have a separator in the form of either a geotextile or a geogrid. This aggregate form, this layer gradually sinks in and you may get an inter mixing of the fines from the sub grade in the aggregate layer. This may lead to piping failure of the strength of this aggregate itself is impair and if you have a separator we can increase the performance because the strength of the aggregate is preserved for a much longer period. Then we prevent the piping and that means that the strength of the sub grade is also preserved.

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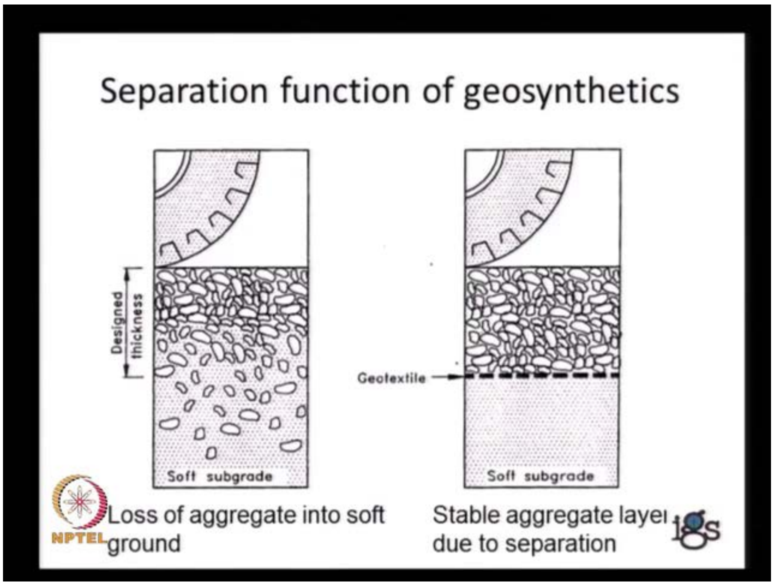

The same separation function is illustrated better here this particular slide is from the international geosynthetics society website without a separator this stone aggregate just slowly disappears into the soft sub grade. If you have a geotextile layer or a geosynthetic layer as a separator, the integrity of this layer is preserved and it stays for a much longer time it provides a very good base for the pavement.

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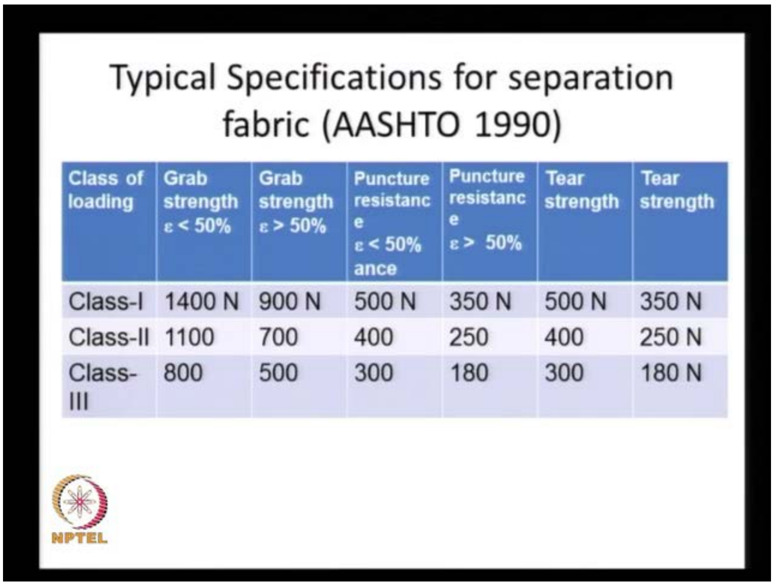

Typical Specifications for separation fabric (AASHTO 1990)

Class of loading	Grab strength ε < 50%	Grab strength ε > 50%	Puncture resistance ε < 50% ance	Puncture resistance ε > 50%	Tear strength	Tear strength
Class-I	1400 N	900 N	500 N	350 N	500 N	350 N
Class-II	1100	700	400	250	400	250 N
Class-III	800	500	300	180	300	180 N

Some of the specifications that are used as a separator or given in the AASHTO for three different classes of loading class one, class two, class three. The grab strength when this strength is mobilized at a strain less than 50 percent 1400 Newton’s. When the same strength is mobilized at a much larger strain epsilon greater than 50 percent, we should have at least 900 Newton’s for class one type of loading. Then the puncture resistance 500 Newton’s for stiffer geogrid and 350 Newton’s for a softer geogrid or a geotextile where this puncture resistance is mobilized at a strain greater than 50 percent.

The tear strength once again for epsilon less than 50 percent and epsilon greater than 50 percent are 350 and 500. So, these are just guidelines that we can find in most of the standards and depending on the particular application that we have we have to analyze. Then properly choose a fabric that has good strength and good opening size h, so that it can act as a separator and as a filter.

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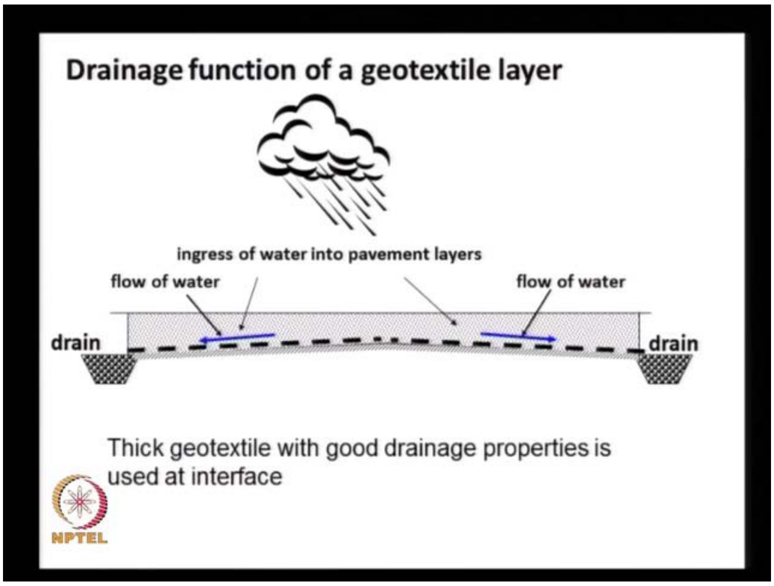

Here, we see the application of thick geotextile as a drainage layer in variably because of the cracks that are present in our road surface of the rain water enters the pavement. Unless we lead the water safely away from the pavements the rain water may enter the sub grade and that to prevent the rain water from entering the sub grade. We can provide good drainage layer and lead the water into some side ditches or side drains is actually we will see this how to design the geotextile to serve as a drain drainage layer in some other lecture.

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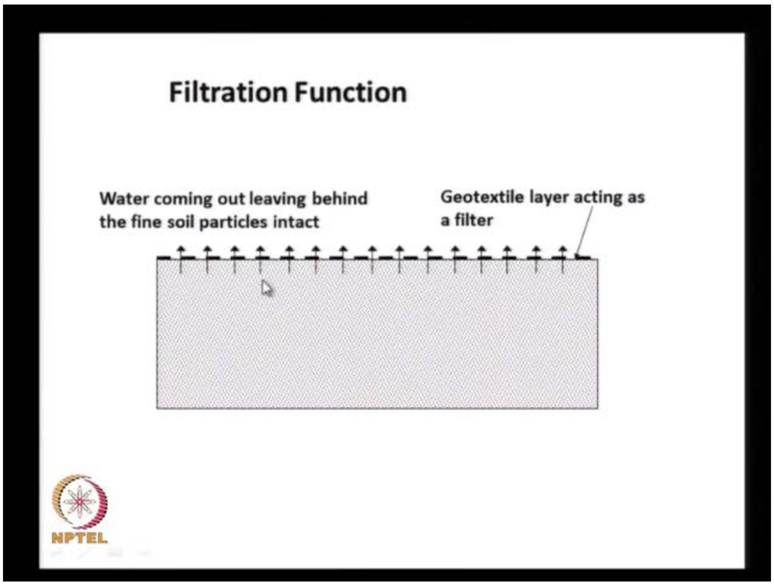

Here, we see the filtration function of a geotextile the only the water should come out and it should leave all the fine soil particles in the sub grade that is we do not want any piping failure to happen. The piping is the loss of fines forms the sub grade leading to the loss of integrity and loss of strength. This geotextile layer should have proper opening sizes consistent with properties of the soil that we have at this side and that once again we will discuss how to select a proper geotextile with having some appropriate opening sizes in some other class.

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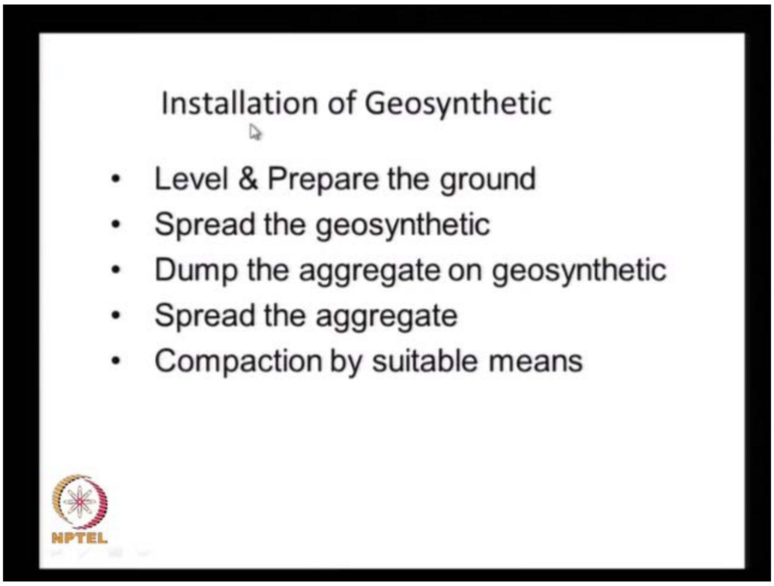

So, how do we install the geosynthetic for our construction purposes? These are the steps, when we go to the site we need to level and prepare the ground and later we spread the geosynthetic and we dump the aggregate and then spread the aggregate. Finally, compact the aggregate by suitable means.

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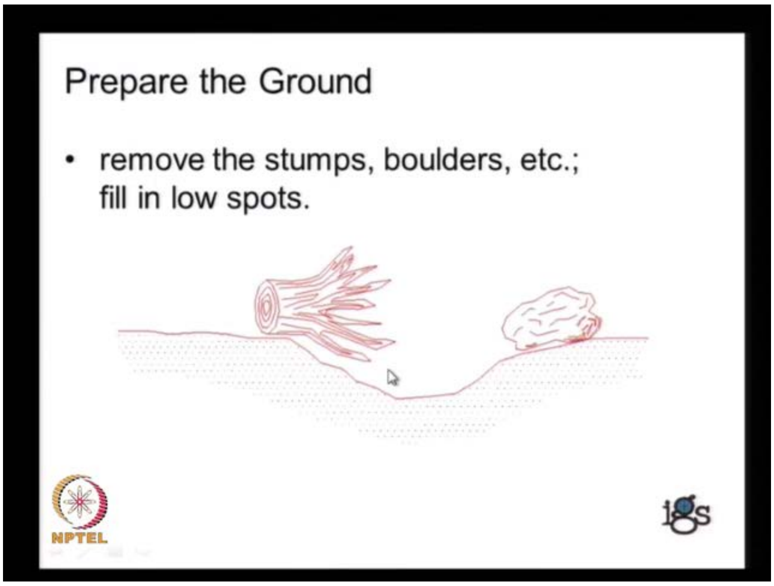

These are the different steps when we go to the site we remove all the roots of the trees and stumps or large boulders and if you have any low spots we fill them and level the ground.

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The prepared ground we stretch, the geogrid or geotextile and we should pin them down because sometimes these geogrids may be so stiff or they have a memory. They just simply roll back and that case we need to pin them down. It is also very important that when we spread the geotextile or geogrid there should not have too many wrinkles.

There should be some tension given, so that right from the initial loading itself the geosynthetic is subjected to tension unless some strain is developed in the geosynthetic.

It will not be able to mobilize its tensile capacity and if there are too many wrinkles you need a very large rut depth to mobilize some tensile force. So, it is very important that when we install the geosynthetic, there should not be any wrinkles and it should be tensioned as much as possible, and pin down before we do the actual other part of the construction.

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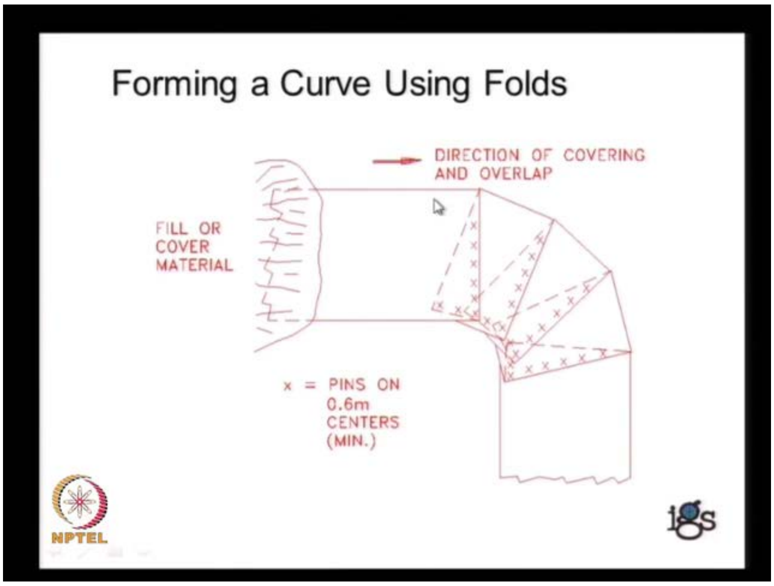

Whenever we have a curve, we can either achieve the curve by folding or the fabric as indicated like this and once you fold it you pin it down, so that we do not lose the curve or we can use the cut pieces to achieve the curve like this.

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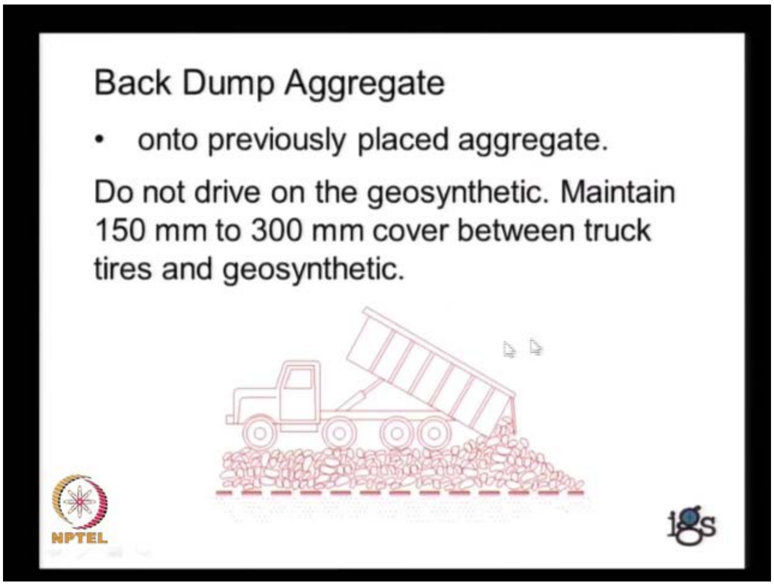

Once we lay the geosynthetic, we dump the aggregate and are very important that our dump trucks or the compaction vehicles do not directly travel on the geosynthetic. If you directly travel, the geosynthetic may get damaged and it is recommended that at least 150 to 300 millimeters cover is given between the truck tires and the geosynthetic in order to protect the integrity of the geosynthetic.

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This is how it happens; we dump the aggregate and then spread it.

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The spreading usually done by some dozers like this, just simply push the aggregate h and in this particular case we see the geocell reinforcement being used can spread the aggregate.

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Then, final step is compaction and usually we compact by using roller compacters and to compact aggregate materials like the granular materials, we use vibro rollers that are not only we apply static force, but some vibration is achieved. If we are dealing with a clay soils we have other type of rollers with sheep’s feet roller and by using suitable type of rolling equipment we can achieve the compaction.

The quality of compaction is always monitored in terms of the proper density against the proactive density and we achieve at least 95 percent protected density after compaction. This is usually checked by doing the field density test either by sand replacement methods or by using the nuclear density gages we can monitor the densities. So, thank you very much, that is a brief description of the design of the flexible pavements and how we can use the geosynthetics and some aspects of the construction.

Thank you very much.