Geosynthetics Engineering: In Theory and Practices
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Module - 05
Lecture - 21
Geosynthetics in Pavements

Welcome to lecture number 21, my name is professor J. N. Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India. The name of the course Geosynthetics Engineering in Theory and Practice, this module 5 lecture number 21, Geosynthetics in Pavement.

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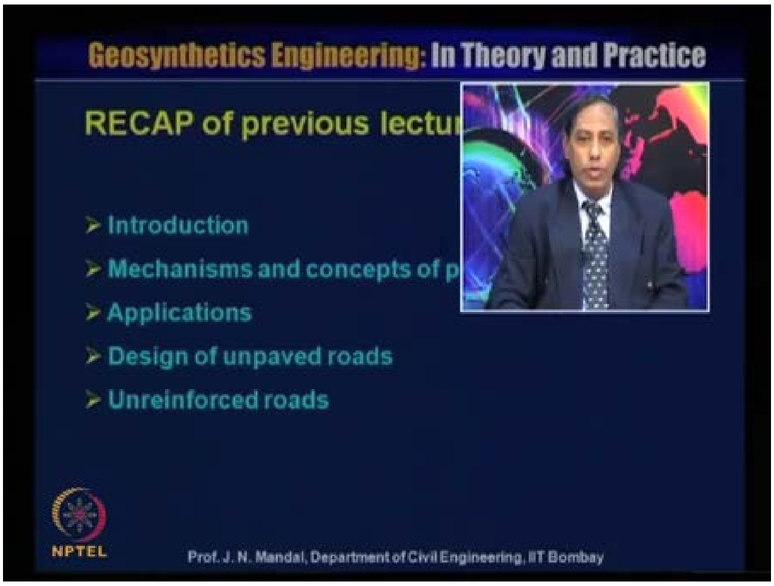

Recap of previous lecture, we have covered introduction, mechanism and concept of the pavement, application, design of unpaved roads and unreinforced road. Now, I will address the design of reinforced road.

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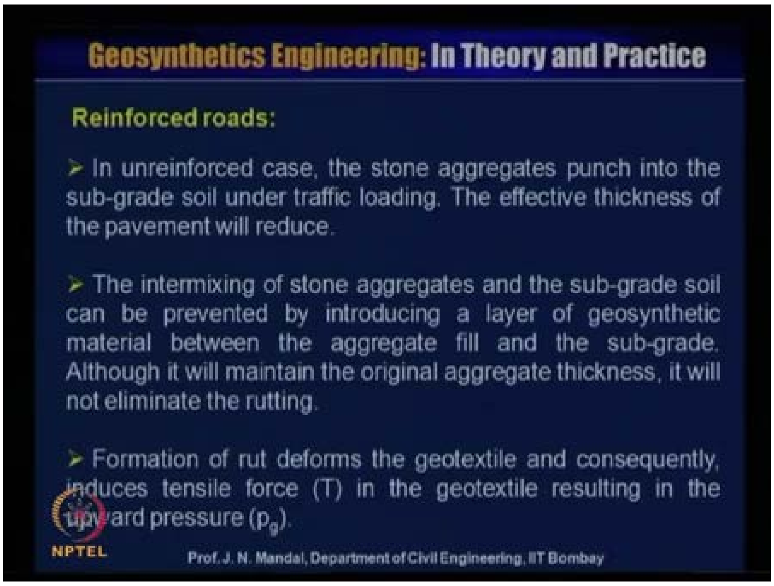

In unreinforced case, the stone aggregate punch into the sub grade soil under traffic loading, the effective thickness of the pavement will reduce. The intermixing of the stone aggregate and the sub grade soil, can be prevented by introducing a layer of geosynthetics material between the aggregate fill and the sub grade. Although it will maintain the original aggregate thickness, it will not eliminate the rutting. The formation of rut deform the geotextile and consequently reduces tensile force T, in the geotextile resulting in the upward pressure p g.

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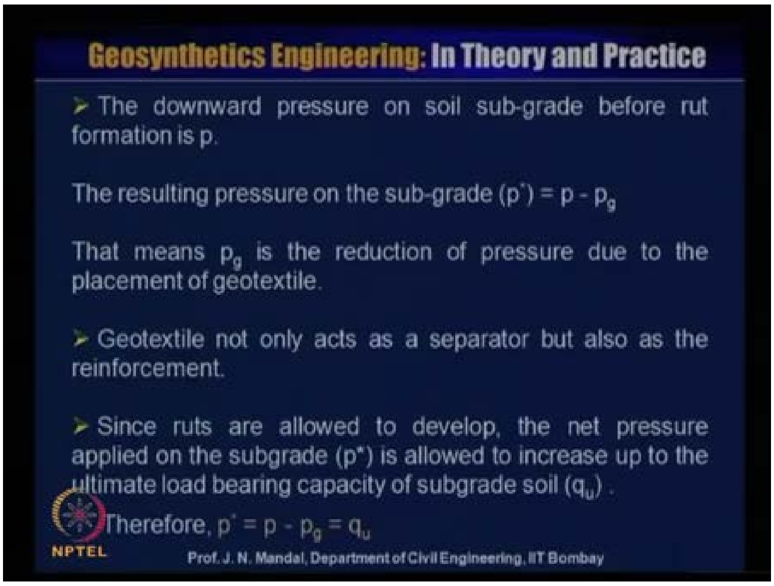

Now, downward pressure on soil sub-grade before rut formation is p, the resulting pressure on the sub-grade p star will be equal to p minus p of g.

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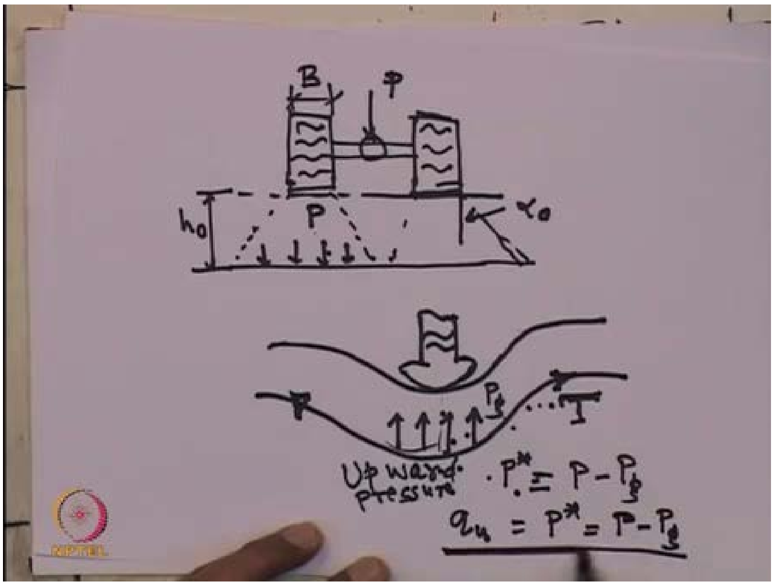

That means, so it means that due to the downward pressure on the soil sub-grade, before rut formation is P, so resultant pressure on the sub grade will be, if it is degenerated p of star, there is a upward pressure, this is upward pressure beneath the wheel load. So, that means, this is the initial pressure the P when there is no reinforcement and then, when you are introducing the geosynthetics material, which will act as a tension membrane, and there is a development of the upward pressure and that is the P of g.

So, resultant pressure will be P star, will be equal to P minus P of g, this is P minus P of g this means that P g is the reduction of pressure due to the introduction of the geosynthetics material. So, here geotextile material not only act as a separation, but also act as a reinforcement and since, the rut are allowed to develop the net pressure applied on the sub grade that is P star, is allowed to increase up to the ultimate load bearing capacity of the sub-grade soil. And that of the sub-grade soil is designated at q of u that means, q of u is equal to P of star is equal to P minus P of g .

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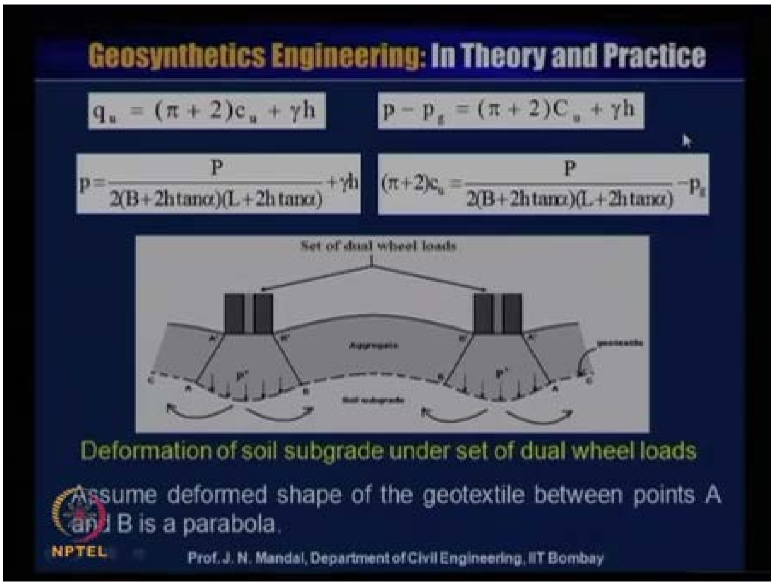

So, now what is q of u, q of u is equal to pi plus 2 into C u plus gamma into h, because with the geotextile material the limiting pressure can be increased to the ultimate bearing capacity of the soil. And that soil q u is equal to pi plus 2 into C u into gamma h, now what is q u, ((Refer Time: 07:37)) q u is equal to p minus p g. So, you can write q u p minus p g is equal to pi plus 2 into C u plus gamma h, now from this you can calculate this small p. So, p will be equal to you know the earlier equation P divided by 2 into B plus twice h tan alpha into L plus twice h tan alpha plus gamma h.

Now, here pi plus 2 into C u, pi plus two into C u will be equal to p minus p g and you know earlier what is p, so p is this, so you substitute in the value of p this minus p g and gamma h and gamma h is cancelled from both sides. So, we can write in case of the reinforcement pi plus 2 into C u is equal to P divided by 2 into B plus twice h tan alpha into L plus twice h tan alpha minus p of g.

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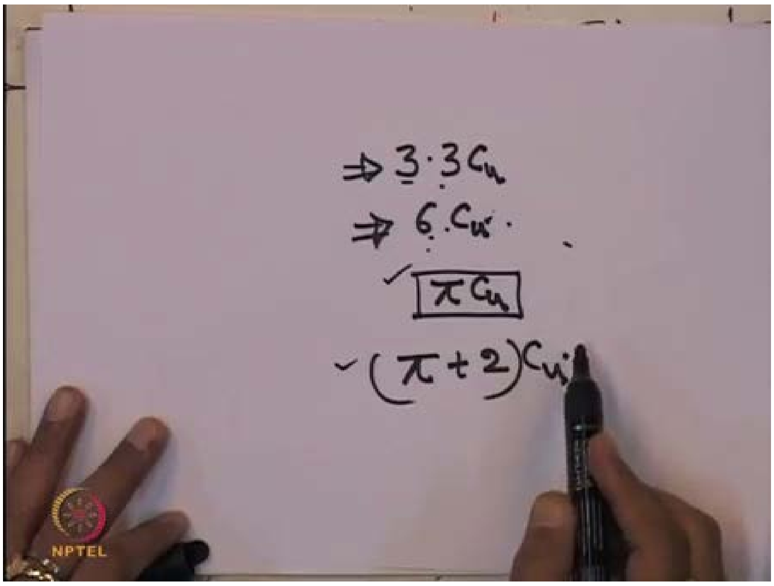

Now, Barenberg and also van den has given that rut begin at 3.3 C or what you call C of u without geosynthetics material, and with the geosynthetics material this value is 6 into C u. So, Barenberg and van den have performed number of the filters with and without geosynthetics material, and this is much more realistic value that without geotextile material rut begin at 3.3 into C u and with geotextile material rut begins at 6 of C u.

So, what we have observed that, in case of unreinforced we consider it pi into C u, you can see when there will be no geosynthetics material, we mention that p is equal to pi into C u. So, this pi into C u almost equivalent to this 3.3 into C u nearer, and in case of with geotextile material this equation is pi into 2 into C u, this is almost equal to 6 of C u nearer some approximation on that basis, so whatever the Giroud and the Noiray adopted the theory is quite reasonable.

Now, ((Refer Time: 11:11)) here the deformation of the soil sub grade under the set of dual wheel load, so assume the deform shape of the geotextile between the point A and B is a parabola. So, this is a set of dual wheel load and this is the geotextile material, this is the soil sub-grade, you can see due to the application of the wheel load, and there is a deformation of the geotextile material is like this. So, you assume that this deformation shape of geotextile, between the point A and B is a parabola, and this is the P star.

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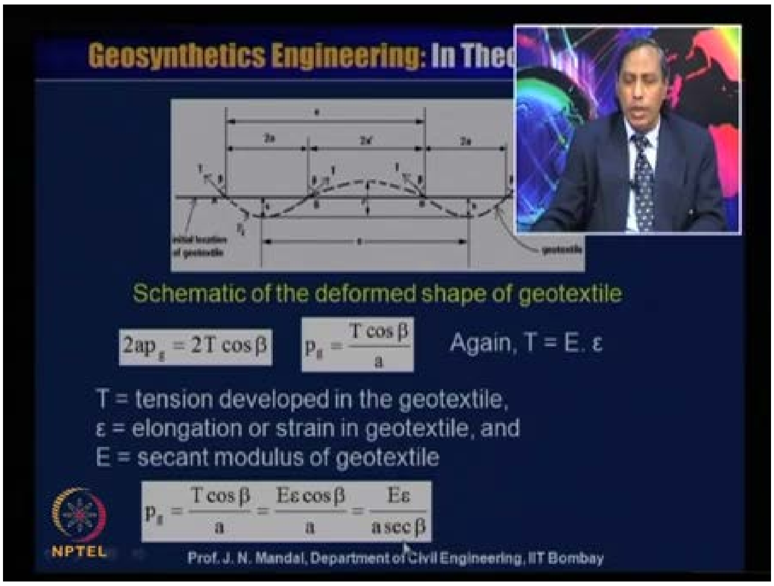

Now, this is a schematic deformation shape of the geotextile material, this is for the wheel load like this going up and then, going down and going up, this is a geosynthetics material. And there is a development of tension T, which is making at an angle of beta and this distance is equal to 2 a and this is 2 of a dash this is 2 of a and this is the T which is making at an angle B, at the point A and this B.

And from this to this distance is e, now from this schematic of deformed shape of geotextile, we can write this is 2 of a into P of g due to geotextile material is equal to 2 T into cos beta this angle is beta, here is a tensile force of geosynthetics material. So, T into cos beta, this also T into cos beta, so 2 T cos beta will be equal to this is 2 a and this is the P of g. So, 2 a p g will be equal to 2 T cos beta. So, you can write p g is equal to T cos beta by a, now again you know this is the T mean tension develop in the geotextile material.

And T is equal to E into epsilon, where E is second modulus of geotextile and epsilon is the elongation or strain in the geotextile material. Now, this tensile force that depend upon the what should be the geotextile modulus, what should be the geotextile strain, what will be the rut depth, what should be the axial geometry, so it depend on all these factors. Now, again that p g is equal to T cos beta by a and T is equal to E into epsilon, so E into epsilon cos beta by a, so this is E into epsilon divided by a sec beta, because this is cos beta, so a sec beta.

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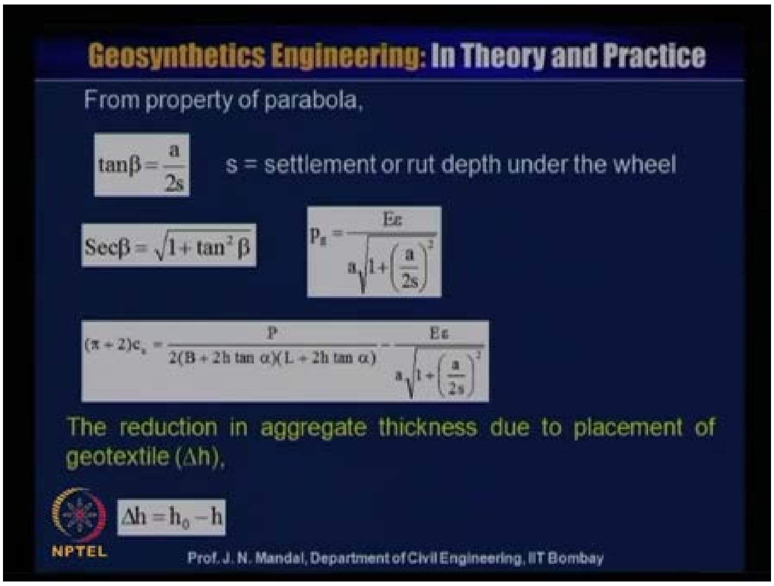

So, now from the property of the parabola, you can write tan beta is equal to a by 2 S, where S is the settlement or rut depth under the wheel load. So, tan beta is equal to a by 2 S, I mentioned that you can say this is the tan beta, and this is the S which is the formation of the rut depth. So, from this parabola, so we can write this is the S and this is T, this is the beta, so from this parabola we can write that tan beta is equal to a divided by 2 S, where S is the settlement or rut depth under the wheel load.

Now, again sec beta is equal to root of 1 plus tan square beta, so we can write p g is equal to E epsilon divided by a into this is sec beta, sec beta means 1 plus tan square beta, because tan beta is equal to a minus 2 S, you substitute with the value of tan beta that means, a by 2 S square. So, ultimately this is the portion, that there is a development of the bearing capacity mainly for the introduction of the geosynthetics material. So, you can see that how the geosynthetics material depend upon the second modulus, and the strain and the geometry and the rut depth and axial load.

So, pi plus 2 into C u is equal to P divided by 2 into B plus twice h tan alpha into L plus twice h tan alpha minus E into epsilon divided by a into root of 1 plus a by 2 S whole square. Earlier I mentioned this equation ((Refer Time: 17:41)), you that for this reinforce case that is pi plus 2 into C u this is minus p g, with that substitute this p g value here, this p g value here. So, that is why in case of the reinforcement, this is the equation we will adopt or this design.

So, from this we will be able to share that what will be the reduction in aggregate thickness, due to the placement of geotextile, let us say that thickness reduction is delta h. So, delta h reduction would be equal to h 0 minus h, h 0 is equal to aggregate thickness without geotextile material, and h is equal to thickness with geotextile material and this is the reduction in aggregate thickness.

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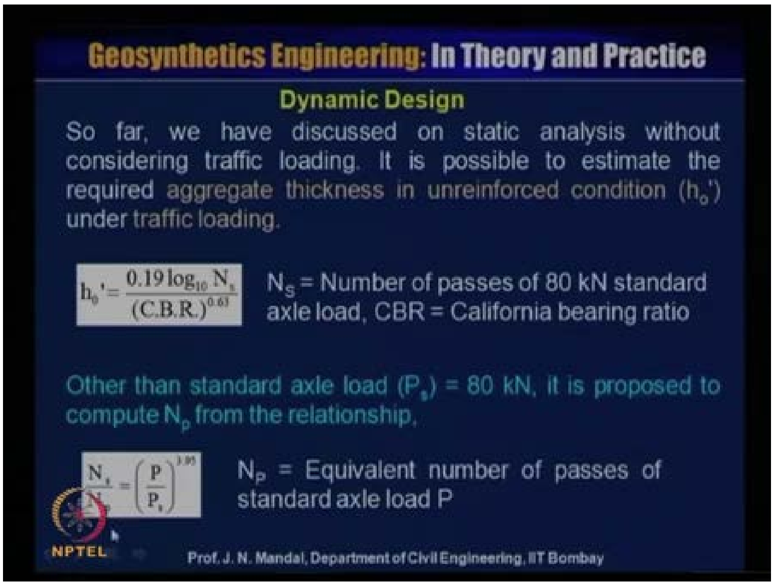

Now, the dynamic design, so far we have discussed a static analysis without considering the traffic loading, it is possible to estimate the required aggregate thickness, in unreinforced condition that is h 0 dash under the traffic loading. So, we can write this equation h 0 dash is 0.19 log 10 N s by CBR whole to the power 0.63, where N s is equal to number of passes 80 kilo Newton standard axle load, and CBR is the California bearing ratio. Other than standard axle load P s is equal to 80 kilo Newton, it is proposed to keep computed N p from the relationship. That means, N s by N p is equal to P divided by P s whole to the power 3.95, where N of p is equal to equivalent number of passes of standard axle load P.

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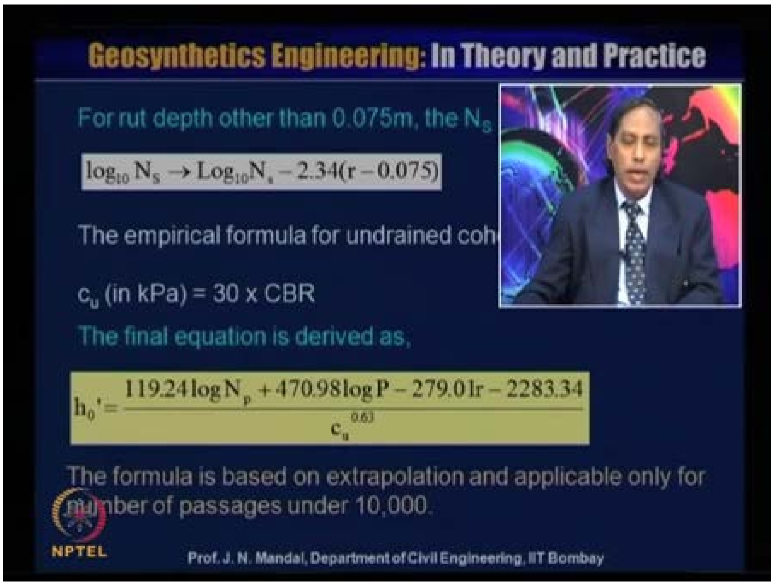

So, for rut depth other than 0.075 the N s is modified by log 10 N s tends to log 10 N s minus 2.34 r minus 0.075, the empirical formula of undrained cohesion C u in kilo Pascal is equal to 30 into CBR. So, you can obtain the final equation derived at h 0 dash is equal to 119.24 into log N p plus 470.98 log P minus 279.01 r minus 2283.34 divided by C u to the power 0.63. So, this formula is based on extrapolation and applicable only for the number of the passage under 10000.

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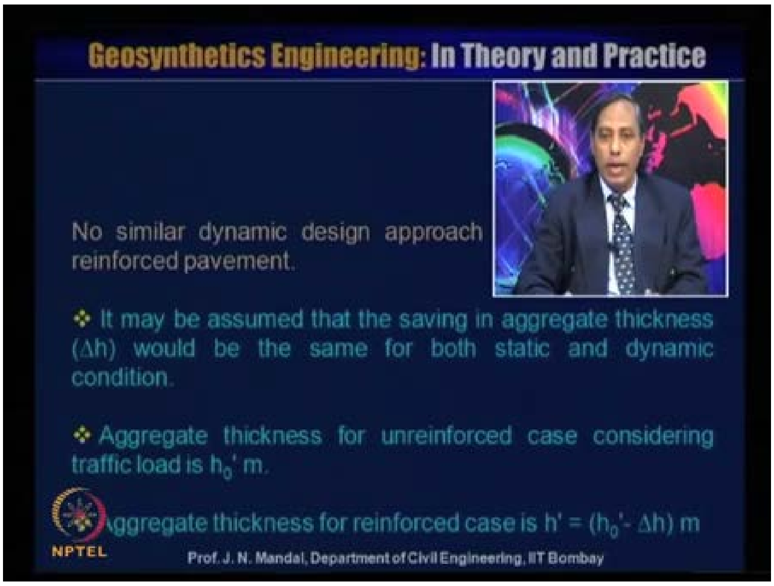

No similar dynamic design approach exists for geotextile reinforced pavement, it may be assumed the saving in the aggregate thickness delta h, would be the same for both static and dynamic condition. Aggregate thickness for unreinforced case considering the traffic load is h 0 dash meter, aggregate thickness for reinforced case h dash is equal to h 0 dash minus delta h meter.

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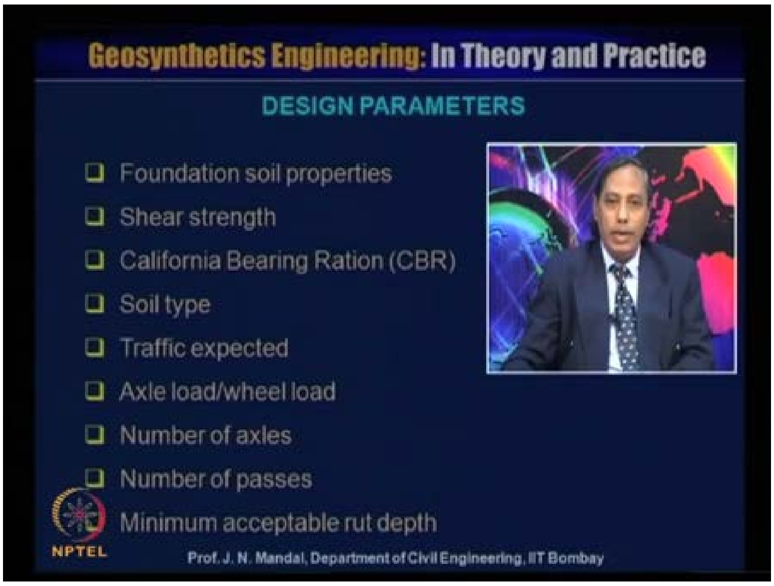

So, when you design what the parameter as required, so you require first of all what will be the foundation soil properties, what should be the shear strength of the soil, what should be the California bearing ratio, or undrained shear strength of the soil. And what is the soil traffic, what will be the traffic expected, what will be the axle load or wheel load, number of the axle, number of the passes and minimum acceptable rut depth, so these are the design parameter are required.

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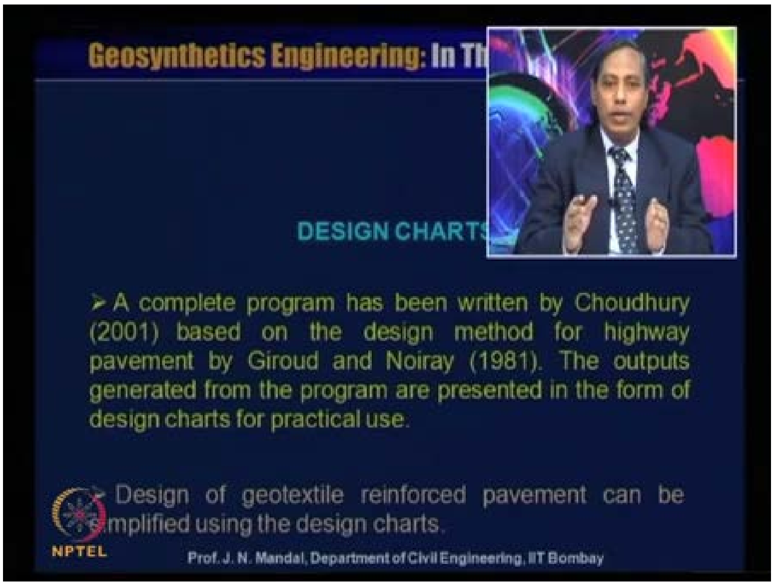

Now, a complete program has been written by Choudhury, 2001 and based on the design method for highway pavement by Giroud and Noiray in 1981; the output generated from this program are presented in the form of design chart for practical use.

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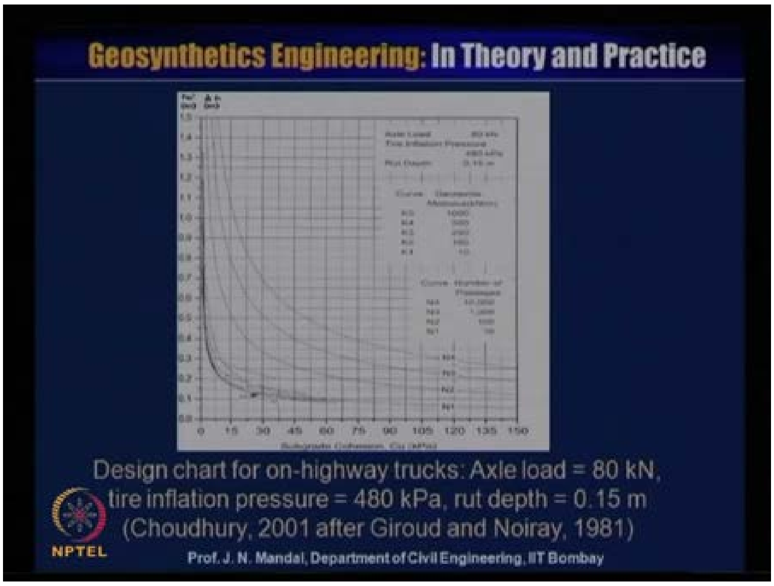

So, design of geotextile reinforced pavement can be simplified using this design chart, so I am just showing you this design chart for on highway truck, where axle load is 80 kilo Newton, and tire inflation pressure is 480 kilo Pascal.

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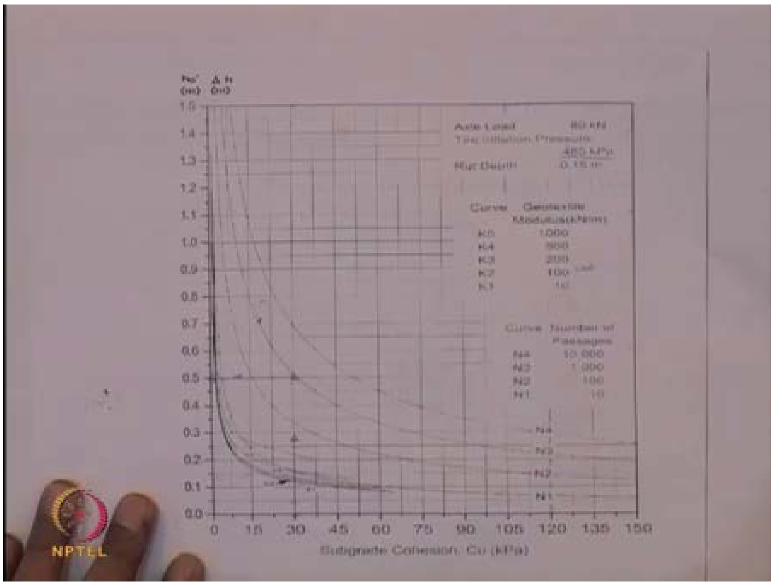

And the rut depth is 0.15 this given by Choudhury 2000, ((Refer Time: 22:32)) after the Giroud and Noiray, 1981. So, in this design chart, this is the relationship between the what will be the sub-grade position value that is C u in kilo Pascal, and this is the thickness of the pavement. And this is the what will be the reduction of thickness in delta h in meter, and this is design chart has been made due to the axle load in 80 kilo Newton, and tire inflation pressure is 480 kilo Pascal and rut depth is 0.15.

And there are many chart this curve that is N 1, N 2, N 3, N 4 that means, N 1 is number of passes 10, N 2 is number of passes is 100, N 3 is number of passes is 1000 and N 4 is number of passes is the 10000. So, when we will use this design chart, first of all we will see what will be the thickness of the pavement without geotextile material, if you know what will be the number of the passes, and if you know what should be the sub-grade cohesion value, or the undrained shear strength value or the CBR value.

Then knowing this sub-grade value and the number of passes, then you can determine what will be the thickness of the pavement. Now, when you are introducing the geosynthetics material, then geosynthetics material as I said, if earlier that it depend also on the geotextile modulus as well as strain. Here this K 1, K 2, K 3, K 4, K 5 are the geotextile modulus value in kilo Newton per meter, suppose K 1 is the 10 kilo Newton per meter. K 2 is geotextile modulus is 100 kilo Newton per meter and K 3 is 200 kilo Newton per meter, K 4 is 500 kilo Newton per meter and K 5 is 1000 kilo Newton per meter.

So, you can calculate this geotextile material based on the stress in curve, then you will be knowing what will be the strain value and what will be the corresponding the modulus value. So, from this chart again, if what will be the sub-grade cohesion and then, what geosynthetics material you are using that means, the geotextile modulus value, whether you want to user K 1, K 2, K 3, K 4, K 5 and accordingly you can also calculate what should be the thickness.

So, this way you can calculate the design thickness and here, that this is horizontal axis represent the undrained shear strength, that is C u of the sub-grade soil. And if the CBR is provided, so you can convert it into equivalent undrained shear strength that means, C u is equal to 30 into CBR in percentage in kilo Newton per meter square. And this vertical axis represent the require aggregate thickness, under dynamic traffic load unreinforced condition that is h 0 dash.

So, it also represents the reduction of the thickness is delta h due to the presence of the geotextile reinforcement, at the geotextile modulus e increases magnitude delta e also increases. So, this is I am showing you that another design chart similar, so here the x axis is a sub-grade cohesion, y axis is the thickness and this is N 1, N 2, N 3 is the number of the passes, K 1, K 2, a set of all 10, 100, 200, 500 and 1000. And here all axle load is 80 kilo Newton rut depth also 1.5, only different that tire inflation pressure is 620 kilo Pascal. So, earlier we took this tire inflation pressure 480 kilo Pascal, and here it is 620 kilo Pascal, so this is the difference, otherwise that you know that how to use this design chart.

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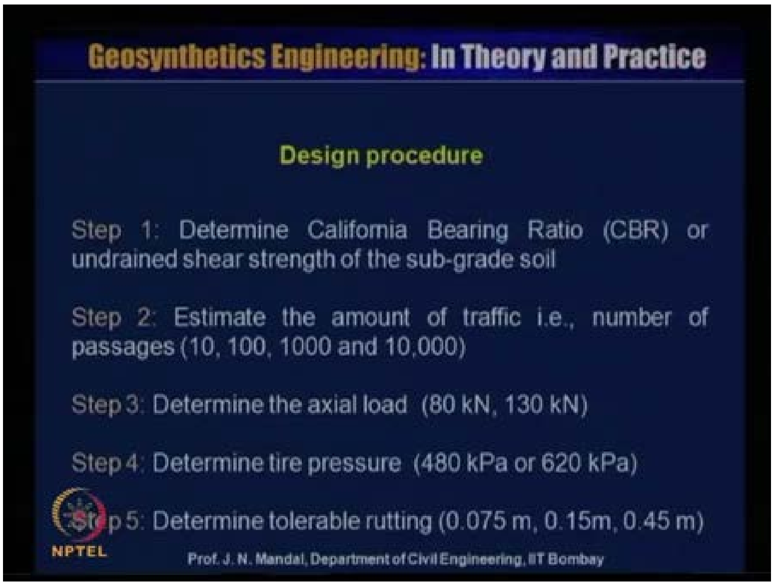

So, now the design procedure determine California bearing ratio step 1 or undrained shear strength of the sub-grade soil. Now, step 2 estimate the amount of the traffic that is number of the passes, whether 10, 100, 1000 or 10000, step 3 determine the axial load, whether it is 80 kilo Newton or 130 kilo Newton. Step 4 determine tire pressure 480 kilo Pascal, and 620 kilo Pascal, I showed you both the chart, so depending up on the type of the tire pressure. So, you can select that design chart and also step 5 that determine the tolerable rutting, that is 0.075, 0.15, 0.45 there are many many available rutting there, so here I have shown in the design chart only for 0.15 meter.

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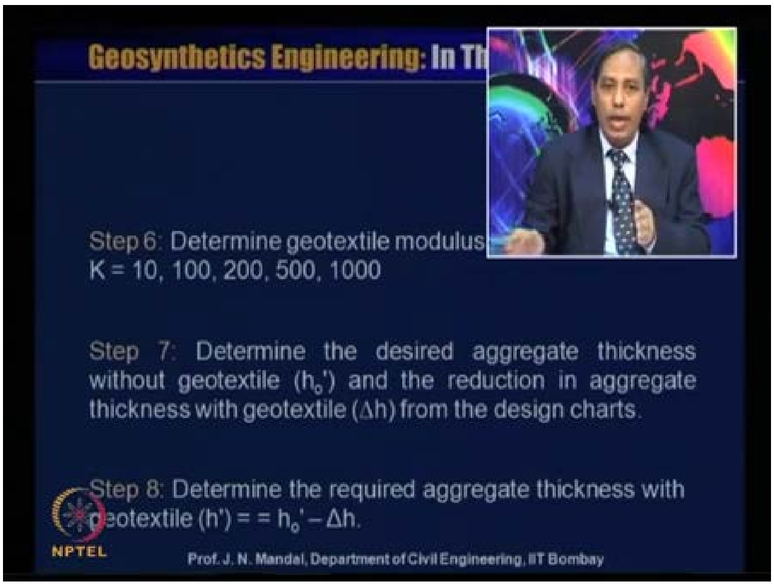

Step 6 they determine the geotextile modulus, I say modulus value may be 10, 100, 500 and 1000 kilo Newton per meter, step 7 determine the desire aggregate thickness without geotextile h 0 dash, and reduction in aggregate thickness with geotextile delta h from the design chart. Step 8 determine the required aggregate thickness with geotextile that is h dash will be equal to h 0 dash minus delta h, and h 0 dash is equal to aggregate thickness without geotextile. And delta h is the what will be the reduction of the thickness with geotextile.

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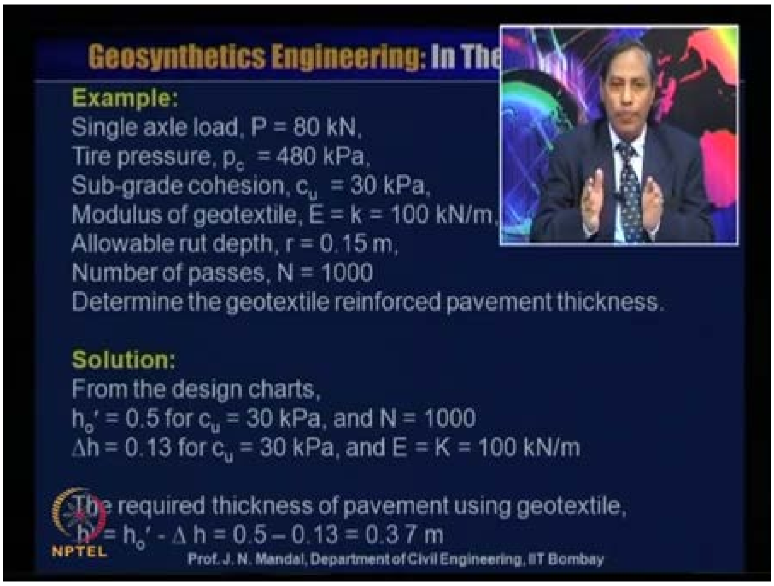

So, here I am now presenting one example, let us say that single axle load P is 80 kilo Newton, tire pressure p c is 480 kilo Pascal, sub-grade cohesion value C u is 30 kilo Pascal. And modulus of geotextile E or k or sometimes also use j is equal to 100 kilo Newton per meter, allowable rut depth r is equal to 0.15 meter, number of passes n is 1000 determine the geotextile reinforced pavement thickness. So, every time you have to make the different design chart, depending up on the axle load and the rut depth, if the rut depth is 0.075, 0.15, 0.25, 0.35, so this design chart will change. So, here in this example we have only considered is allowable rut depth is 0.15.

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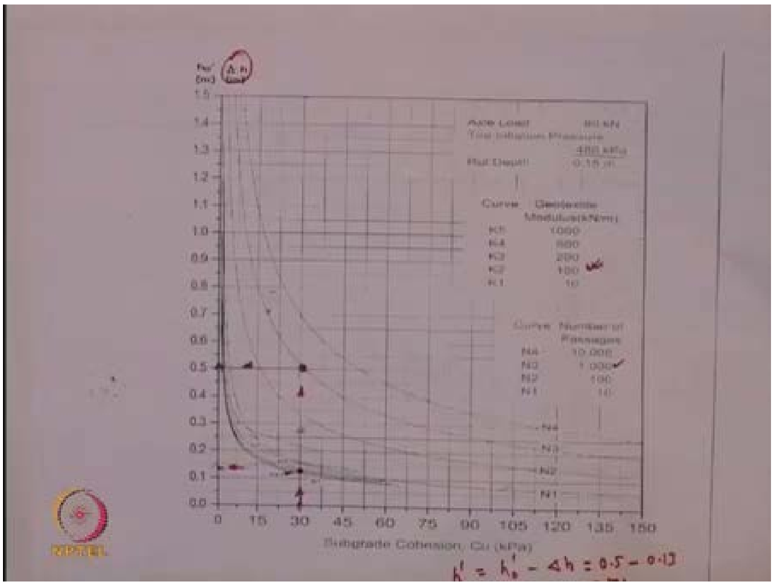

Now, you can look at this design chart, so because we have selected this design chart, because that our axle load is 80 kilo Newton and rut depth is 0.15 and tire pressure is 480 kilo Pascal. And also we know that what will be the C u value, now here in our case, here we have considered that C u value is equal to 30, we know the 30, so from this design chart we have to calculate what is h 0 dash.

So, when the C u is 30 and the you check what will be the number of the passes, number of the passes is 1000, so that means, N 3, so number of the passes is 1000 means this is ((Refer Time: 31:13)) N 3, this is N 3, this is N 3. So, knowing the value of sub-grade cohesion 30, you move up to the when N 3 is equal to 1000 and then, it move horizontally which will meet this y axis, which give the result 0.5 meter that means, h 0 dash will be 0.5 meter.

So, this is the thickness for undrained reinforced case without geosynthetics material, so knowing the C u number of the passes, so you can calculate what will be the thickness of the pavement without geosynthetics. Now, we will proceed for the thickness of the geosynthetics material for reinforced case, now here in this problem, we have considered that geotextile what you call the modulus value. So, what will be the modulus value you have considered here, modulus you considered is 100 that mean K 2 value.

So, K 2 value is somewhere here, so for the same sub grade cohesion value you move up and then, for the geotextile material what will be the modulus geotextile modulus value that is 100 kilo Newton per meter is given and then, you move horizontally on this direction. So, which will meet the y axis, the point that is 0.13, approximately 0.13, so this delta h value will give you that 0.13 value. So, we know that without geotextile h 0 value is 0.5 with geotextile value h delta h value is equal to 0.13.

So, what should be the required thickness of the pavement using geosynthetics material, and that is h of dash is equal to h of 0 dash minus of delta h, so that h of 0 dash is equal to 0.5 that mean this, and with geotextile that is a delta h, so this will be 0.13. So, if you search that from 0.5, 0.13 it will give you about 0.37 meter that means, without geosynthetics material, you have to be provided the thickness of the pavement is 0.5 meter. Whereas, with geosynthetics material you have to be providing the thickness is 0.37 meter only that means, you are saving about the aggregate about 26 percentage. So, you can see all along the road, you are saving this 26 percentage of the aggregate.

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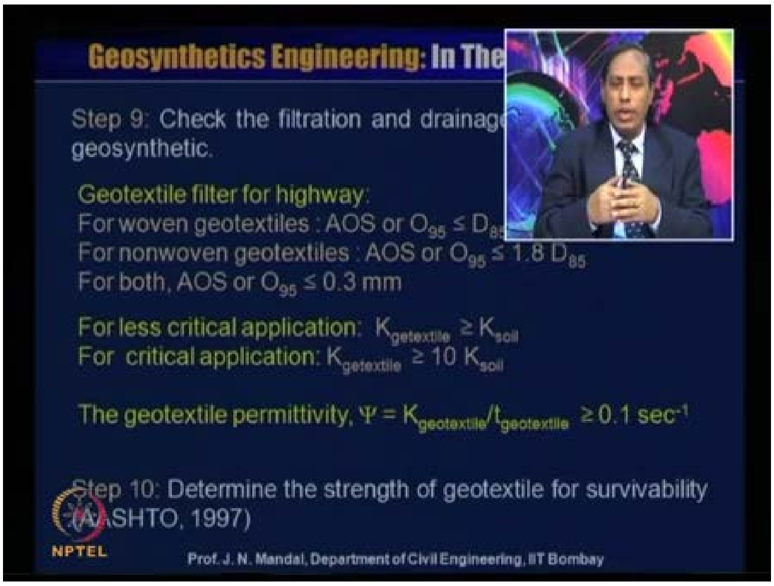

Now, that thickness, but then step 9 you have to check the filtration and drainage characteristics of the geosynthetics material, geotextile filter for the highway for woven geotextile material apparent opening size or O 95 should be less than equal to D 85. For nonwoven geotextile AOS or O 95 should be less than equal to 1.8 into D 85, for both AOS or O 95 should be less than equal to 0.3 millimeter. For less critical application K geotextile greater than equal to K of soil, and for critical application K geotextile should be greater than equal to 10 K of soil, where K soil is the coefficient of permittivity of the geotextile.

And K geotextile is equal to coefficient of permittivity of geotextile, and geotextile permittivity sin is equal to K geotextile by T of geotextile, that mean thickness of the geotextile material, it should be greater than equal to 0.1 per second. So, this already we have discussed in our earlier module, and they know what about the filtration and drainage and erosion control module. Now, step 10 determine the strength of geotextile for survivability that for AASHTO, 1997, so we have also shown that strength of geotextile material in our earlier module.

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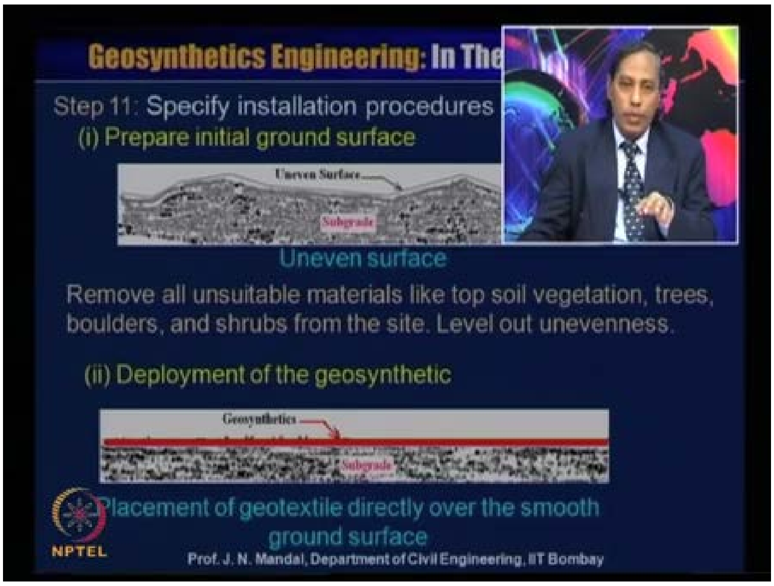

Now, how to design the geosynthetics material for pavement or road construction, now it is also essential to know that how to place the geosynthetics material. So, step 11 we are specifying here installation procedure and site preparation it is important, first prepare the initial ground surface. Because, that in the initially, that in the sub-grade soil is very uneven surface, you have to remove all unsuitable material like top soil, vegetation, trees, boulders, shrubs from the site and level out the unevenness. Otherwise geotextile material may tear it off or damage, so it is essential to make an uneven surface, then deployment of the geosynthetics material. As you seen here red colored this deployment of the geosynthetics material, the placement of geotextile directly over the smooth ground surface.

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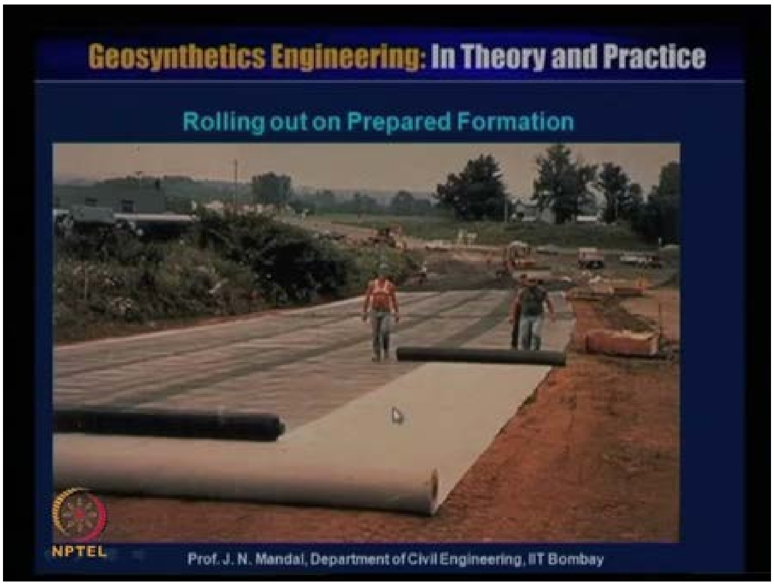

So, you can see that rolling out of the prepared formation, so then you are laying the geotextile material, you can have in the roll form, this width may be about 5 to 6 meter, you can have it in the roll form, it may be about 1000, 5000 running meter length. So, you just to roll it at by manually or by some machine, so you can easy to roll it you can also overlap one with the other, depending up on the value of the California bearing ratio; so you can overlap, you can stitch, you can welded also.

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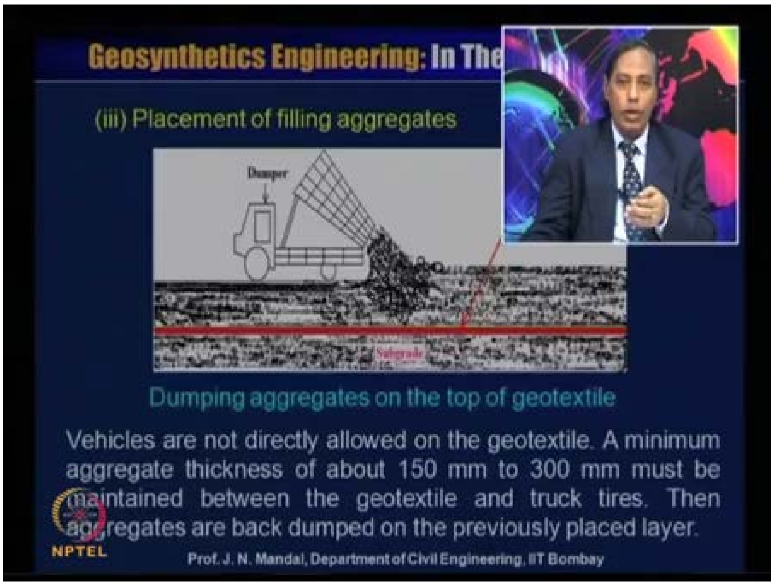

So, next is placement of filling aggregate, then dumping aggregate on the top of the geotextile material, the vehicles are not directly allowed on the geotextile, a minimum aggregate the thickness of about 150 millimeter to 350 millimeter must be maintained between the geotextile and the truck tires. Then aggregate are back dumped on the previous placed layer, if we directly place the aggregate on the geotextile material, then geotextile material may damage or tear it off, so you have to be very careful.

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So, this is the back dump of the aggregate, you are back dumping this aggregate, aggregate is inside the truck you are back dumping this aggregate.

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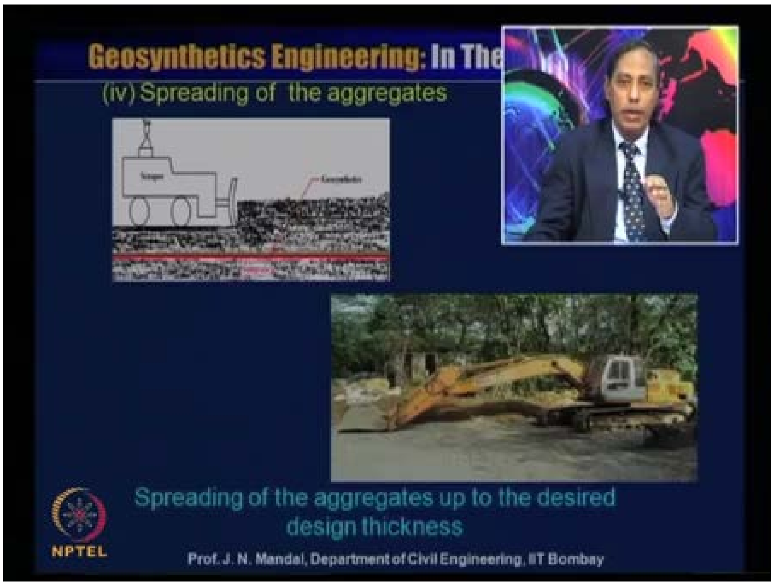

And then, you have to spreading the aggregate with this machines spreading of the aggregate up to the desired design thickness.

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So, you can spread it proportionally, you can see how the spreading of the aggregate, you are spreading this aggregate.

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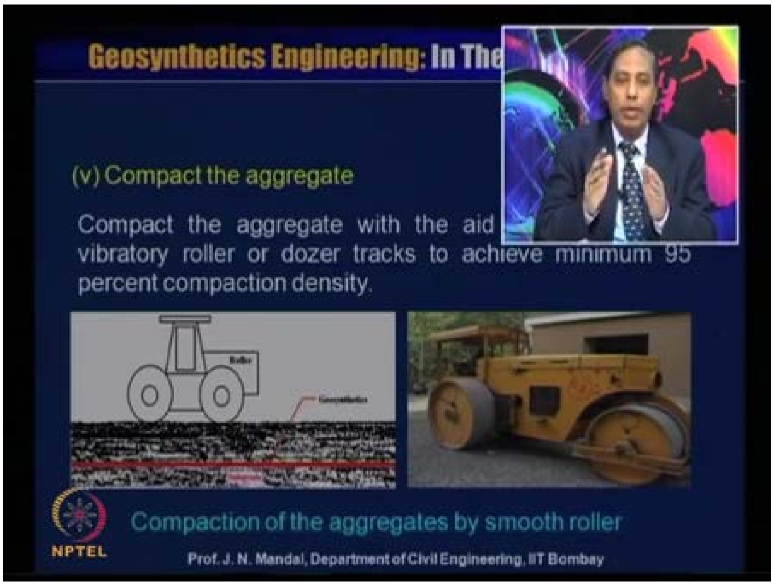

And then, compact the aggregate, compact the aggregate with the aid of smooth drum vibratory roller or dozer tracks to achieve the minimum 95 percent is compaction density. You can see this is the roller which we can use for the compaction, this is the compaction of the aggregate by smooth roller.

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You can see how the compaction of the aggregate by the smooth roller, how it is compacting.

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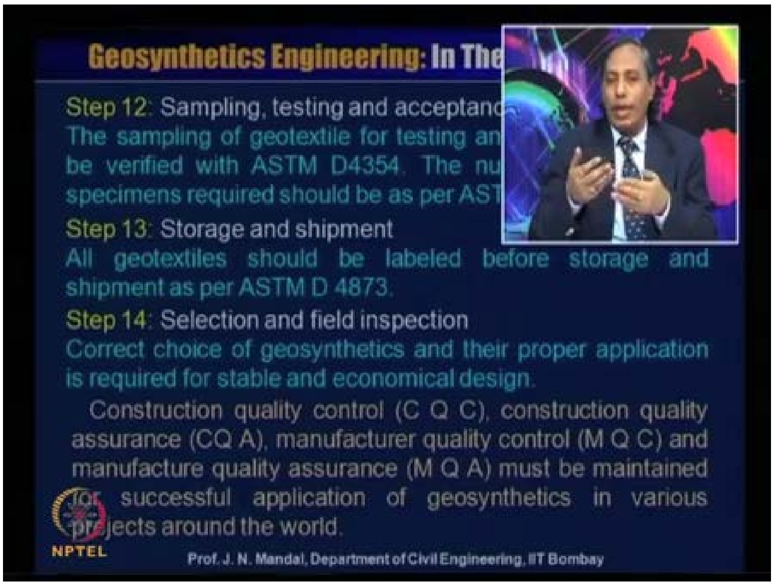

Now, step 12, sampling, testing and acceptance, the sampling of the geotextile for testing and acceptances shall be verified, with the as per ASTM D 4354, the number of geotextile specimens required should be as per ASTM D 4759. If we go through this specification, you will be knowing how many number of geotextile specimens tested are required and whether it is acceptable or not.

Now, step 13 storage and shipment, it is also very important that all the geotextile should be labeled, before storage and shipment as per ASTM D 4873, because you cannot keep in the open in the sunlight, it is their roll should be covered with some kind of the material, protect from the sunlight. So, it is very important that how will you store and how will you also shipment, every time you have to give that what is the sample, what is their label number, it is like a that way you will be knowing detail about the sample.

Step 14 selection and field inspection, correct choice of geosynthetics and their proper application is required for stable and economical design, so that is very important. And also at the same time, you have to go for construction quality control CQC, construction quality assurance CQA. And at the same time you require manufacture a quality control MQC and the manufacture quality assurance MQA, must be maintained for successful application of the geosynthetics in various projects around the world. Otherwise, the manufacturer will say that it is a fault from the designer side, designer side will say it is a fault from the manufacturer side, then contractor, replacement there is a lot of the argument, debate, discussion on the related issue.

So, therefore, it is very much essential to proper kind of the quality control, and the quality construction for both side, construction side and as well as the manufacturer side. Now, when you are placing the geosynthetics material, there is a question of joining of the geotextile material, so you should join properly or you can overlap properly, and what should be the length of the overlap and how will you join.

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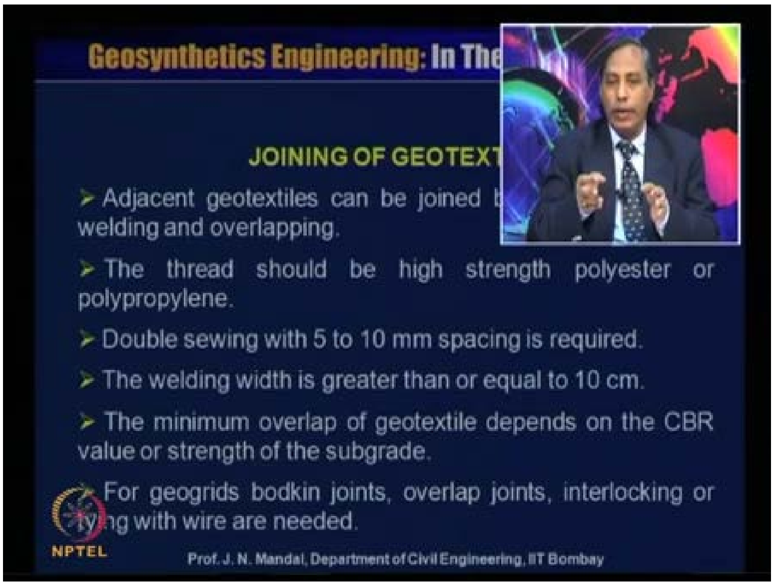

Now, adjacent geotextile can be joined by stitching, sewing, welding and overlapping, the thread should be high strength polyester or polypropylene, double sewing with 5 to 10 millimeter spacing is required. The welding width is greater than or equal to 10 centimeter, minimum overlap geotextile depend on the CBR value or strength of the sub-grade soil, for geogrids bodkin joint, overlap joint, interlocking or tying with the wire are needed.

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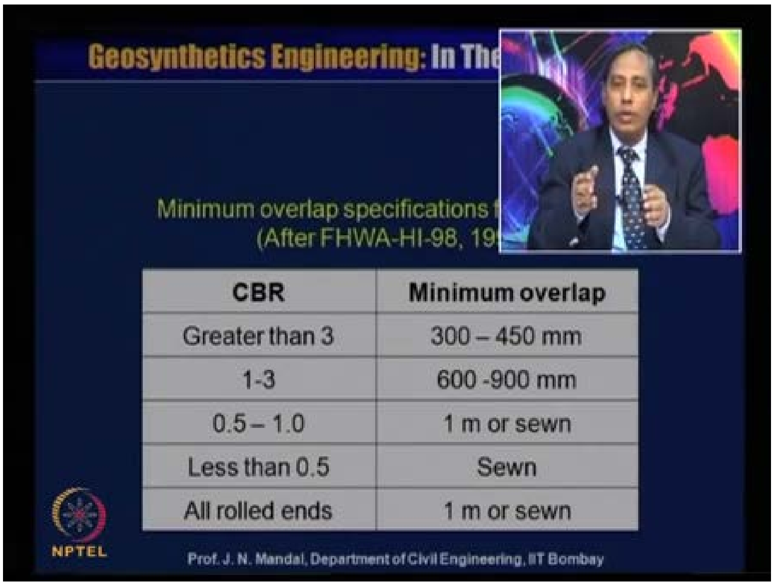

CBR	Minimum overlap
Greater than 3	300 – 450 mm
1-3	600 -900 mm
0.5 – 1.0	1 m or sewn
Less than 0.5	Sewn
All rolled ends	1 m or sewn

So, you can see here the minimum overlap surface for geotextile after FHWA-H1-98, 1998 that CBR and what should be the minimum overlap value. If CBR greater than 3, so minimum overlap 300 to 450 millimeter, if the CBR lies between 1 and 3, then minimum overlap will be 600 to 900 millimeter. If CBR is 0.5 to 1, then minimum overlap should be 1 meter or sewn, if it is a less than 0.5, then sewn and all rolled ends is 1 meter or sewn.

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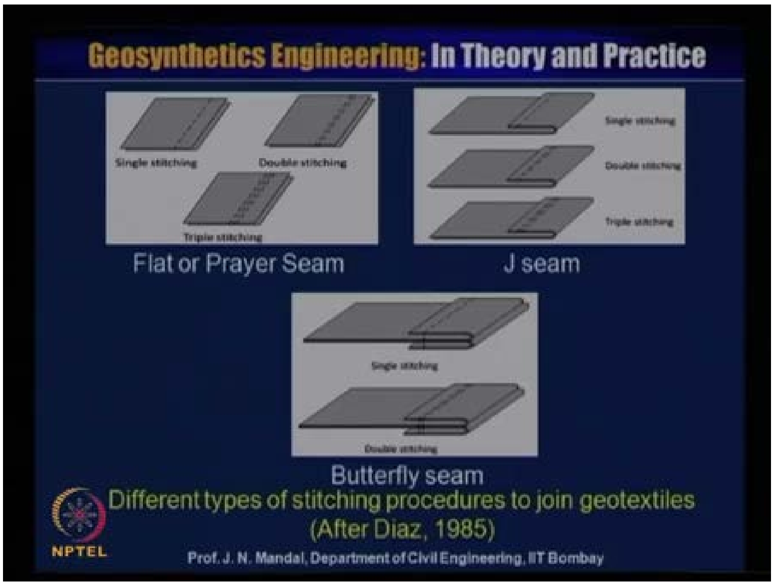

And here, the different types of the stitching procedure to join the geotextile material, after Diaz, 1985 you can say flat or prayer seam this is a single stitching, double stitching, triple stitching. Or J seam with a single stitching, double stitching and triple stitching and to also butterfly seam, it is a single stitching and the double stitching.

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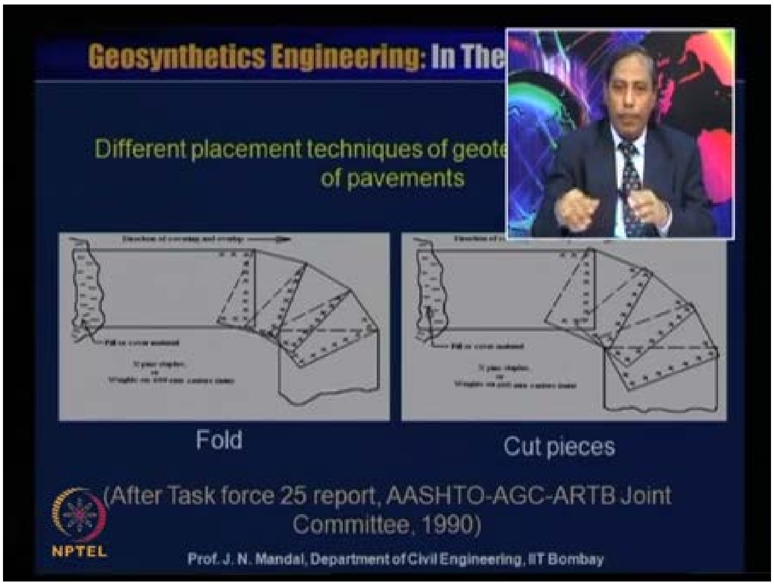

And sometimes you can observe that different placement of techniques of geotextile at the turn of the pavement, so you can adopt either in the fold form or in the cut pieces form, is after task force 25 report AASHTO-AGC-ARTB joint committee, 1990. So, this is the your geotextile material and how it has been used in the fold form and also in the cut piece form, this is direction of coveting and the overlap. And then, you can have some idea from this task force, and how you have to place the geotextile material at the turning of the pavement.

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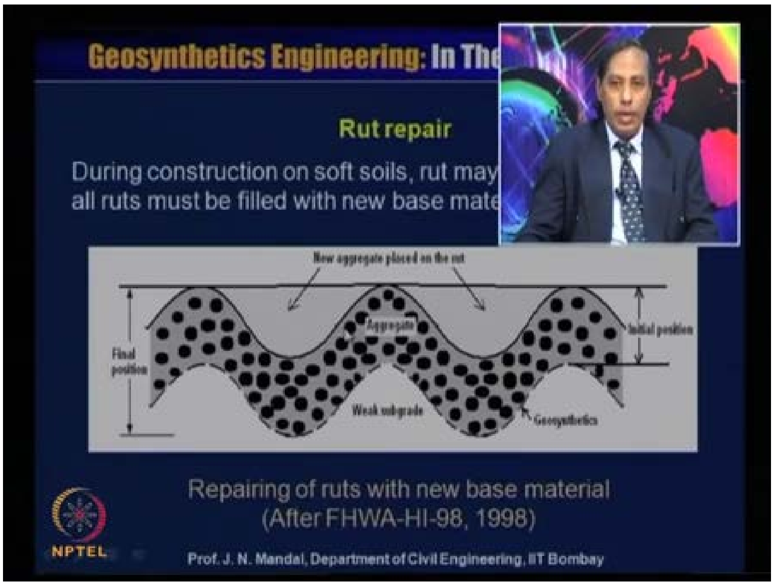

Now, you can observe that, when the wheel load passes through the geotextile material and then, there is a possibility for this kind of the shape, you can see during construction on the soft soil rut may form, in such case the old rut must be filled with the new base material. So, here it is shown that repairing of the rut with the new base material, so let us say this is the initial position, and this is the geosynthetics material was there in the initially.

And due to the full load you can see that the shape of the geosynthetics material that means, ultimately this is the final position, so initially it was here, and this is the final position. Because, the sub-grade soil is very weak and then, there is a formation of rut and this rut is to be filled up with the new aggregate, so you have to place the new aggregate, then on the rut; so this way you can repair the rut with the new base material.

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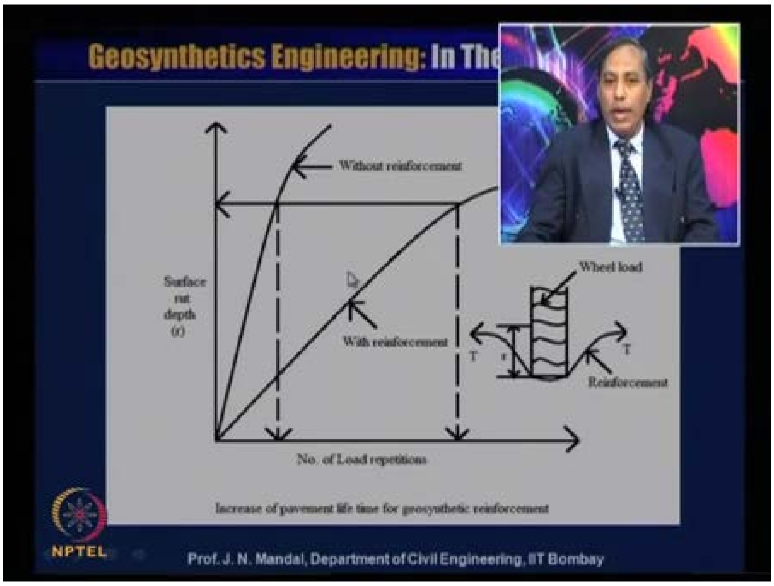

Now, this is shown that increase in the pavement life for geosynthetic reinforcement, this figure show represent between number of load repetition x axis, and this is the surface rut depth r. So, this is the curve between the surface rut depth and the number of load repetition without geosynthetics material, and this is the curve shown that surface rut depth r versus number of load repetition with geosynthetics material. You can see here this is the wheel load, and there is a development of tension and this is the geosynthetics material and this is the rut depth.

So, here you can take a note of it that, when the number of load repetition is less, you can see the surface this ((Refer Time: 48:56)) is here, but due to the introduction of geosynthetics material. You can see the number of load repetition increase, so increase of the pavement life for the geosynthetics reinforcement. So, here you can observe that how the increase of the pavement life time for the introduction of the geosynthetics material as the number of load repetition increases, but at the same time it increase the pavement life time.

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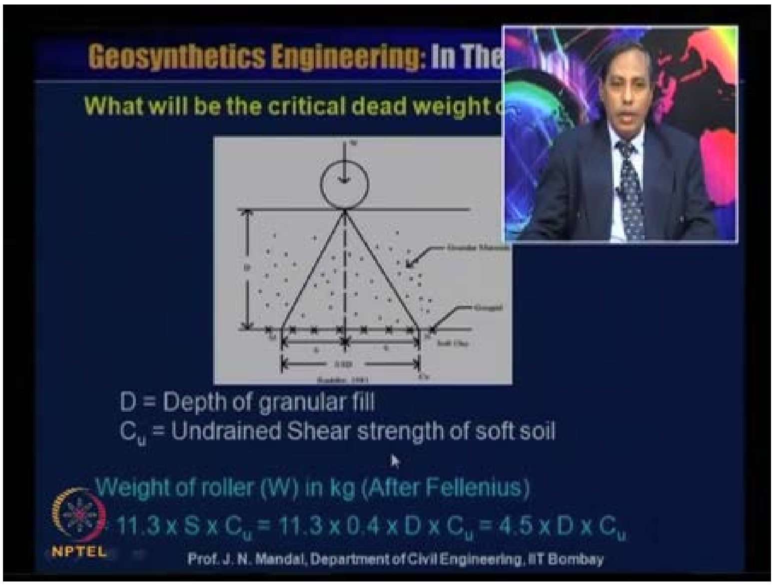

Now, what will be the critical dead weight of vibro-roller, so here this is the weight of the roller W in K g, this is after Fellenius and this is a depth of the granular fill, so this is a granular fill and this is the geosynthetics material. And this is 0.8 times of the D and this is distance S, this distance is S and D is the depth of the granular fill, and C u is the undrained shear strength of the soil.

So, here given the equation that what will be the weight of the roller in K g, W is equal to 11.3 into S into C u, so 11.3 and that what is S if this is a total is h of D, so this will be the 0.4 D. So, this is point 4 D into C of u, so this will give you 4.5 D into C u, so W is equal to 4.5 D into C u, so if the depth, if that C u or the undrained shear strength of the soil, so you can calculate what will be the weight of the roller that means, W in K g.

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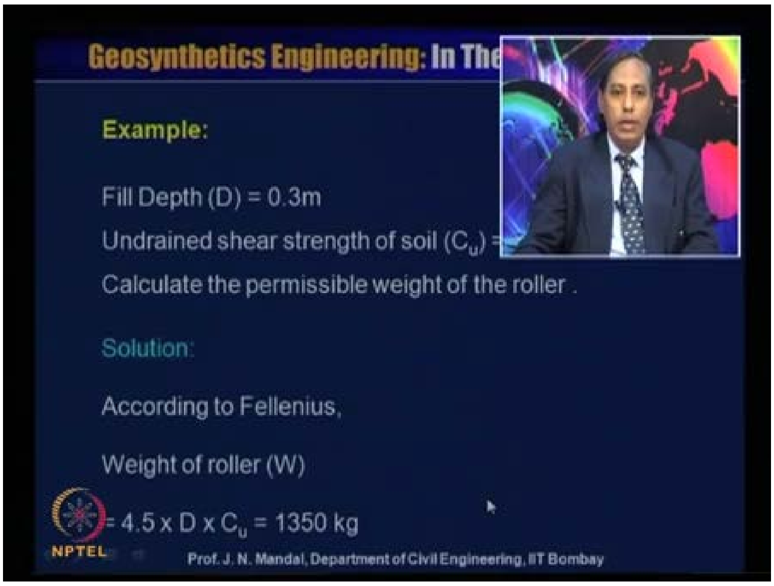

Giving one example that full depth D is equal to 0.3 meter, undrained shear strength of the soil C u is equal to 1000 K g per meter square, so calculate that what will be the permissible weight of the roller. So, here is the solution according to the Fellenius equation, the weight of the roller W is equal to 4.5 D into C u, so you substitute value of D 0.3, C value is 1000 K g per meter square, so this will give you that 1350 K g; so weight of the roller will be the 1350 K g.

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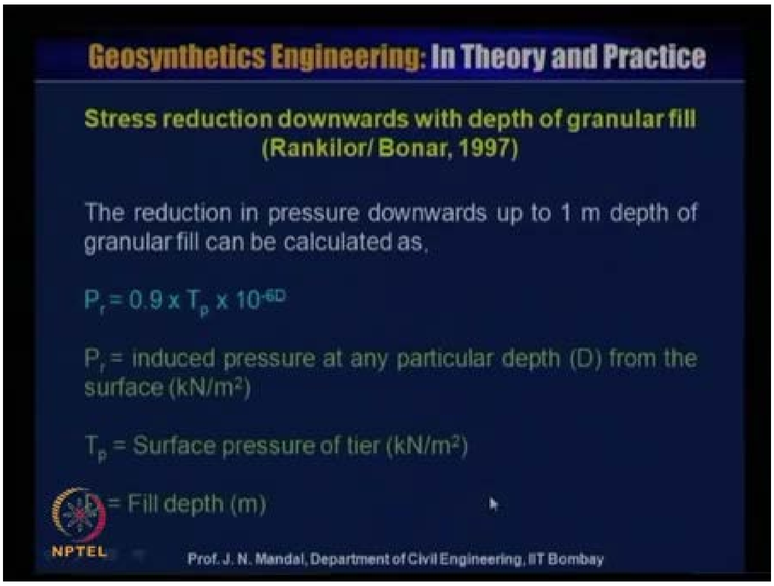

So, you have that idea about you would that what will be weight of the roller for this example, also that how do design the reinforce soil, using the various design chart. And these design chart also depend up on what will be the axle load, what should be the rut depth, what will be the number of the passes. And then, you can calculate the what will be the thickness of the pavement, and how this geosynthetics can help to reduce the thickness of the pavement drastically. So, you can save a lot of money and the time, any question.

Thank you for listening.