Geosynthetics Engineering: In Theory and Practices
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Module - 05
Lecture - 22
Geosynthetics in Pavements

Welcome to lecture number 22, 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 22 Geosynthetics in Pavement.

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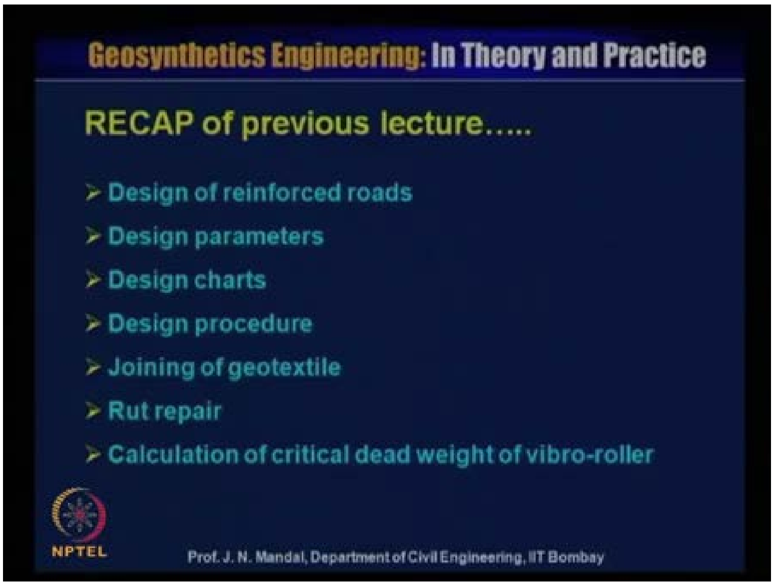

Recap of previous lecture, design of reinforced road, design parameters, design chart, design procedure, joining of geotextile, rut repair, calculation of critical dead weight of vibro-roller, so these are which we have covered in our earlier lecture.

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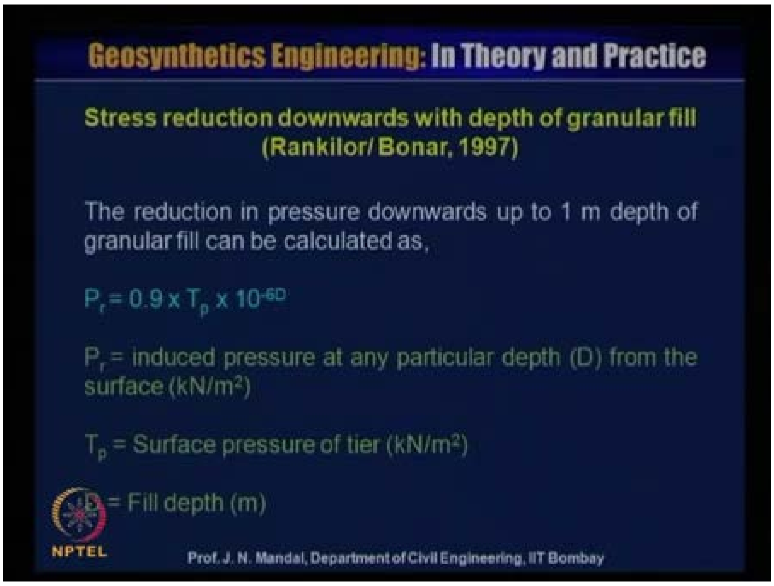

Now, we will explain the stress reduction downward with depth of granular fill, that is Rankilor and Bonar, 1997. The reduction in presence of the downward up to 1 metre depth of the granular fill, can be calculated using this equation, that is P r is equal to 0.9 T p into 10 to the power minus 6 D. Where P r is induced pressure at any particular depth D, from the surface that is kilo Newton per metre square and T p surface pressure of tire this is kilo Newton per metre and D is the fill depth that is in metre.

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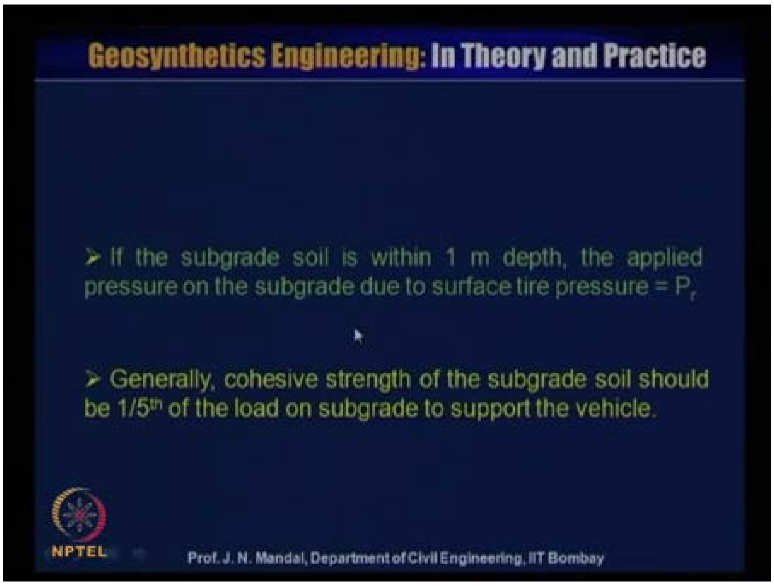

So, if the sub-grade soil is within 1 metre depth. the applied pressure on the sub-grade due to the surface tire pressure P r, generally cohesive strength of the sub-grade soil should be 1 5th of the load on sub-grade to support the vehicle.

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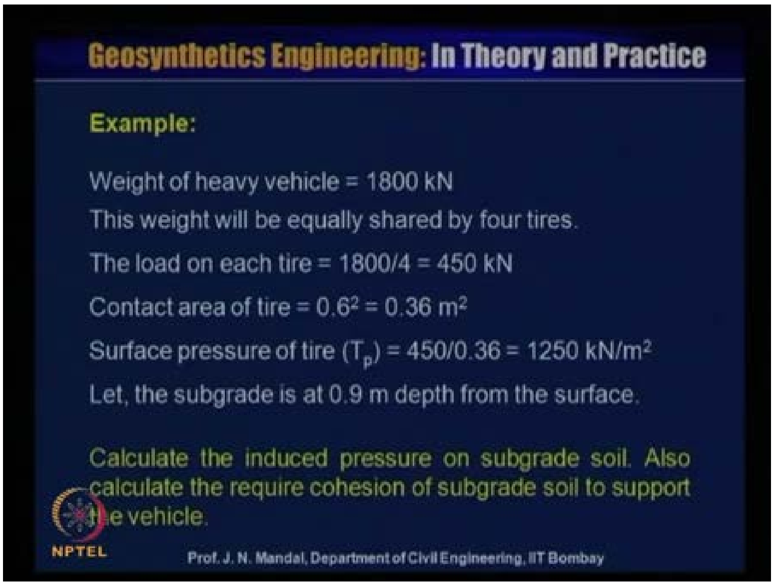

Here I am giving one example, let us weight of the heavy vehicle is 1800 kilo Newton, this weight will be equally shared by 4 tire. So, therefore, load on each tire will be equal to 1800 divided by 4 is equal to 450 kilo Newton, and contact area of the tire is 0.6 square that is equal to 0.36 metre square. Surface pressure of tire T p is equal to 450 divided by 0.36 is 1250 kilo Newton per metre square, let the sub-grade is at 0.9 metre depth from the surface. Calculate the induced pressure on sub-grade soil, also calculate the required cohesion of the sub-grade soil to support the vehicle.

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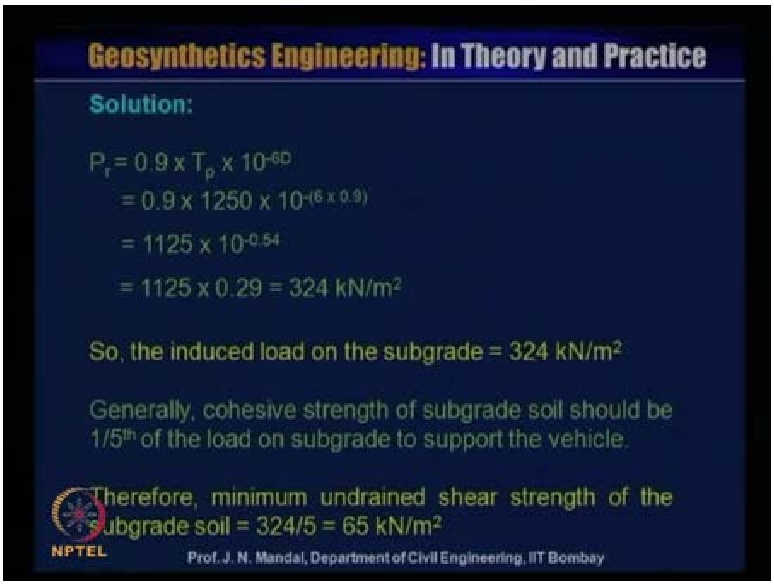

Now, here is the solution we know the equation P r is equal to 0.9 T p into 10 to the power minus 6 D is equal to 0.9 T p is given 1250 into 10 to the power minus 6 into D is 0.9. So, if we calculate, then you will have P r is equal to 1125 into 10 to the power minus 0.54 is equal to 1125 into 0.9 is equal to 324 kilo Newton per meter square. So, induced load on the sub-grade is 324 kilo Newton per meter square, generally cohesive strength of sub-grade soil should be 1 5th of the load on the sub-grade to support, the vehicle. Therefore, minimum undrained shear strength of the sub-grade soil, is equal to 324 divided by 5 is 65 kilo Newton per meter square, so we will now discuss advantage of the unpaved road.

Maintain the separation between the sub-grade and the sub-base, reduce the required amount of good quality aggregate, minimize the rut depth, construction of road is very easy, site preparation is less. Reduce the depth of excavation, prevent contamination or migration of the sub-base material, prevent failure of pavement structure, improve drainage system. Provide stabilization, reduce intensity of stress on the sub-grade and reduce differential settlement, extend the life of pavement and reduce maintenance requirement.

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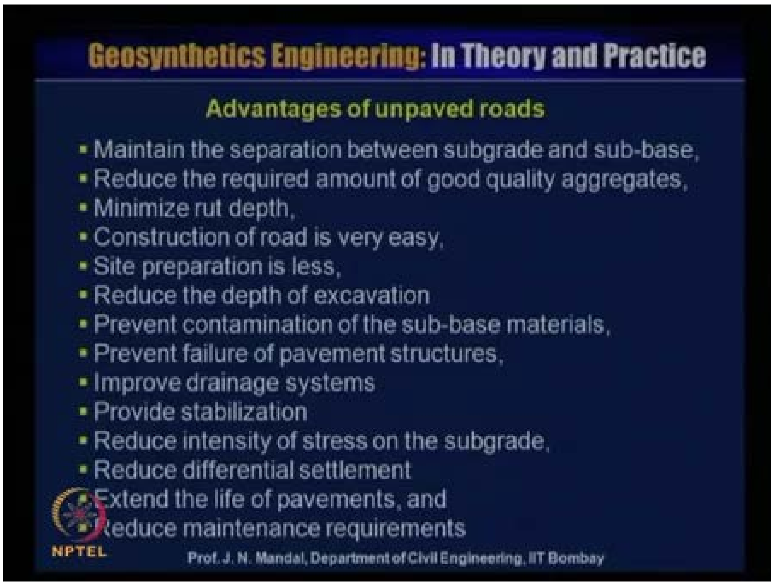

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Now, I will address the design chart of US forest service, USFS for unpaved roads, Steward et al, 1977 developed a design method for US forest service, this method has the following limitation. The aggregate layer is cohesionless non plastic and compacted to CBR is equal to 80, undrained shear strength of the sub-grade is about 90 kilopascal or CBR less than 3, vehicle passage less than 10000, geosynthetics serviceability criteria should be considered.

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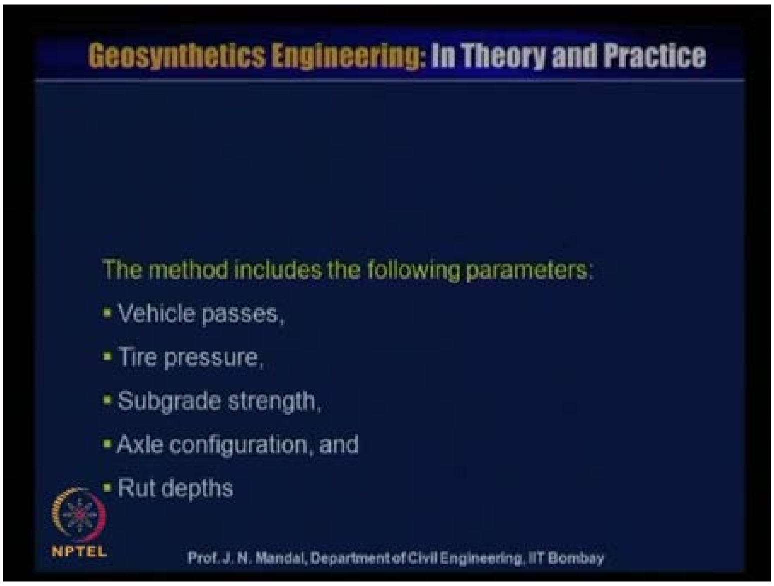

This method includes the following parameter, vehicle passage, what will be the tire pressure, what will be the sub-grade strength, what will be the axle configuration and rut depth.

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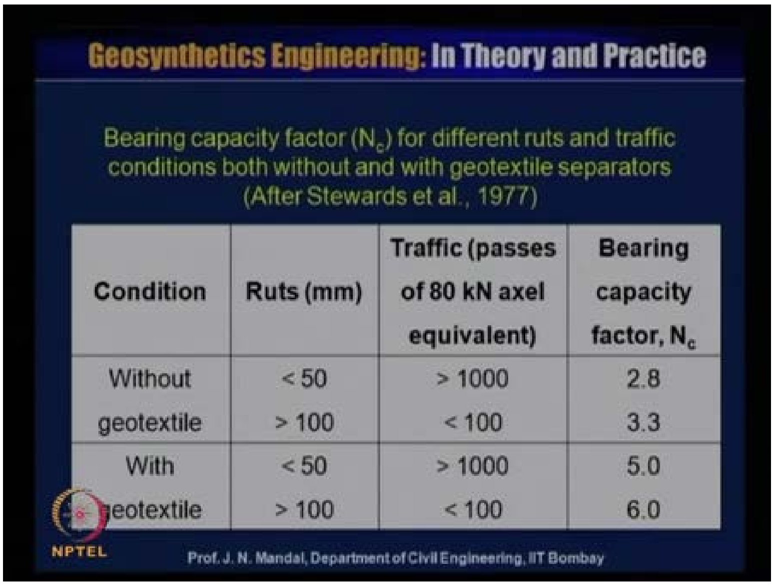

So, this table gives that condition rut and the traffic, and what will be the bearing capacity factor, we will calculate the bearing capacity factor using this table, depending upon the rut traffic and number of the passage. So, bearing capacity factor N c for different rut and traffic condition both without, and with geotextile separator, this is after stewards, 1997.

So, here condition when without geotextile, and rut is less than 50 millimetre, but traffic passage of 18 kilo Newton axel equivalent greater than 1000, then bearing capacity factor is N c is equal to 2.8, this you have to remember. When the rut is greater than 100 millimetre, but traffic number less than 100, then the bearing capacity factor N c is equal to 3.3. And with geotextile if the rut less than 50 millimetre and traffic is greater than 1000, then bearing capacity factor N c value is 5.

And when the rut greater than 100millimetre and traffic is less than 100, then bearing capacity factor N c is equal to 6. So, we will determine that N c factor without and with geotextile, and we will check up what is the benefit of the use of the geotextile material in unpaved road.

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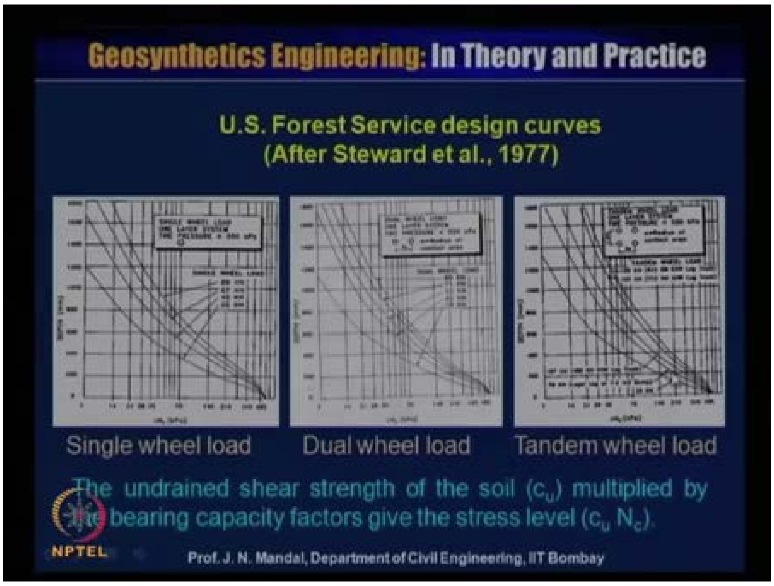

So, this US forest service, this is the design curve and different design curve have been prepared, this for the single wheel load, this is for the dual wheel load and this is for the tandem wheel load. So, here is the single wheel load, and the tar pressure is 550 kilopascal, and for the dual wheel load also that tar pressure is 550 kilopascal, and also the tandem wheel load the tar pressure is 500, so we can use this chart as per requirement.

So, this will give you the what will be the undrained shear strength in this axis and then, the what should be the depth in millimetre that means, from this chart we have to calculate the C into N c or C u into N c. So, we know from the site what will be the undrained shear strength of the soil that means, C u and when you know the C u value, so you can also calculate what will be the CBR value. And then, from that you can you know what will be the value of N c, you can calculate the what will be the bearing capacity factor.

And this multiplication of C u and the bearing capacity factor you can obtain C u into N c, so whenever you know that C u into N c, then for a particular that wheel load whether 22, 45, 67 or 89, so you can directly determine that what will be the thickness of the pavement. Whether it is a single wheel load, dual wheel load and a tandem wheel load, so this way we will calculate the what will be the thickness of the pavement, I will give one example later on.

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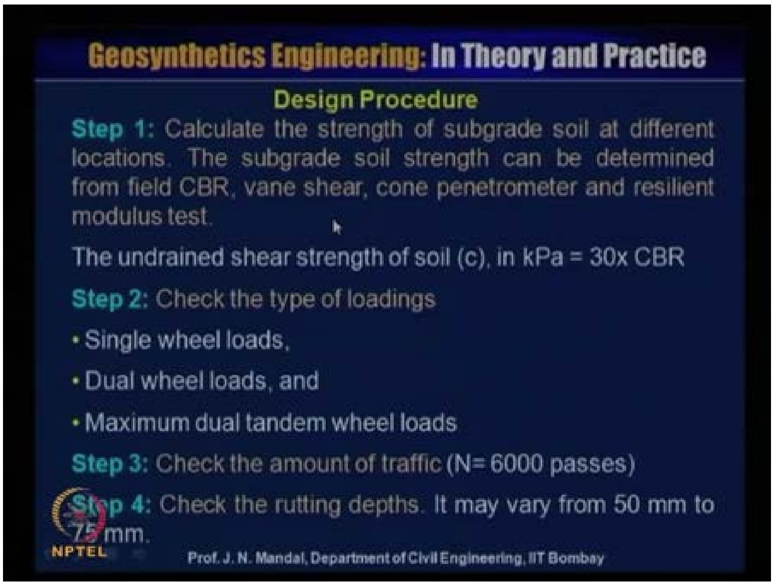

So, this is the procedure step 1, that calculate the strength of the sub-grade soil at different location, this sub-grade soil strength can be determined from the field CBR, vane shear, cone penetrometer and resilient modulus test. So, when you can calculate the what should be the CBR value, then you can calculate also undrained shear strength of the soil C is equal to 30 into CBR, that is in terms of kilopascal.

So, either you can determine what will be the undrained shear strength of the soil, or if you calculate the CBR, then you can calculate what will be the undrained shear strength of the soil, that you multiplied by 30 into CBR. Step 2 check the type of the loading, so it may be single wheel load, it may be dual wheel load or even may be maximum dual tandem wheel load.

So, I have shown you that earlier, the different chart is there, so accordingly you have to be select that, what is the type of the loading you have considered in the design.

Step 3 you check the amount of traffic, let us say N is equal to 6000 passage and step 4 check the rutting depth, it may vary from 50 millimetre to 75 millimetre.

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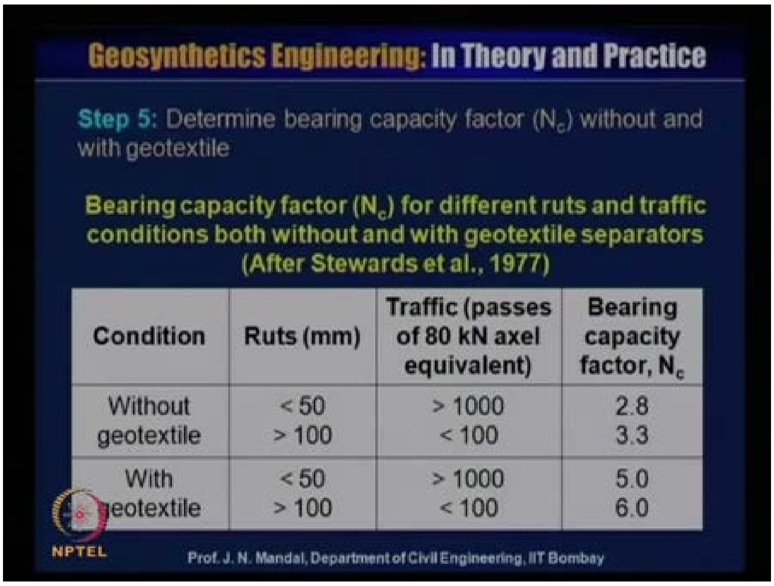

Step 5, determine the bearing capacity factor N c without and with geotextile material, now bearing capacity factor N c for different rut and traffic condition, both without and with geotextile separator is given by stewards et al, 1977. Here we are talking about the rut, if without geotextile, if it is less than 50 millimetre, then traffic is greater than 1000, then bearing capacity factor N c is equal to 2.8. If the rut greater than 100, and traffic is less than 100, then bearing capacity factor in N c is 3.3.

With geotextile if rut less than 50 millimetre and traffic greater than 1000, then bearing capacity factor N c is 5, then rut greater than 100 millimetre less than 100 traffic, then bearing capacity factor is 6, so we can determine from this table that will be the bearing capacity factor.

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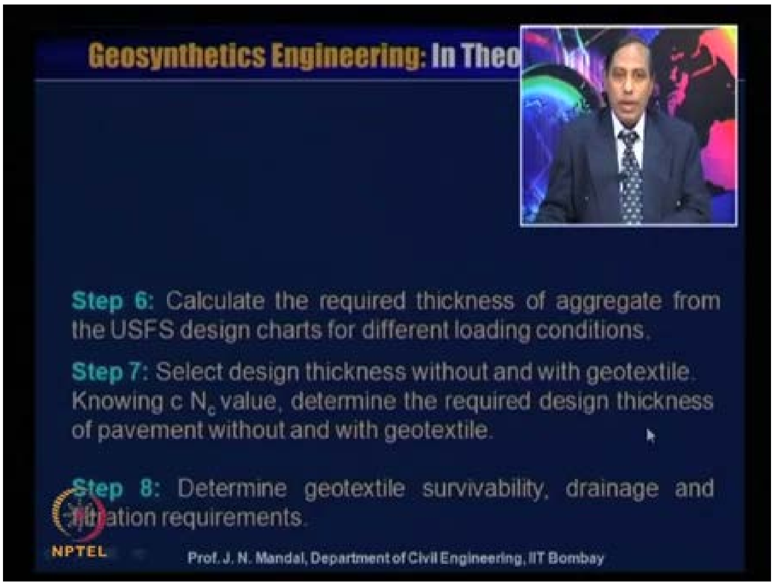

Step 6, calculate the required thickness of aggregate from the USFS design chart of different loading condition. Step 7 select the design thickness without and with geotextile, knowing the value of C into N c value, determine the required thickness of pavement without and with geotextile. Step 8 determine geotextile survivability drainage and the filtration requirement.

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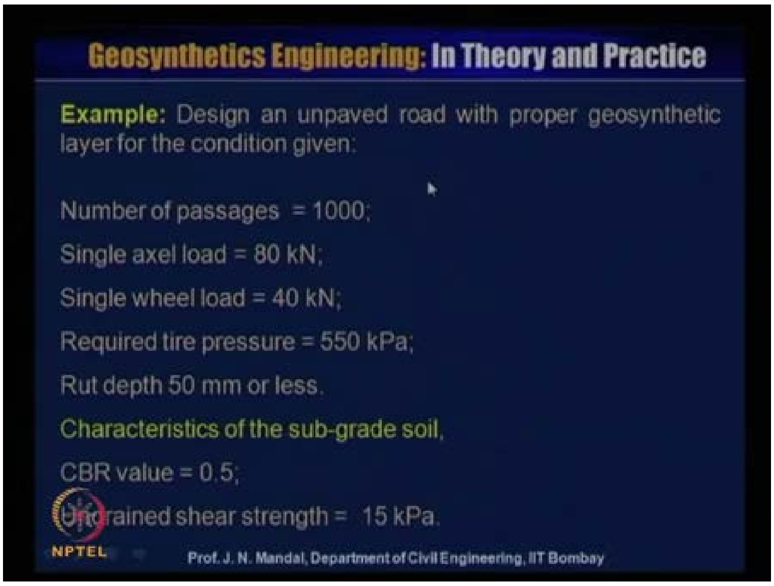

So, this one example is given, then it will be more clear to you, it has design and unpaved road with proper geosynthetics layer for the condition given, number of the passages 1000, single axel load is 80 kilo Newton. So, single wheel load will be the half of axel load that means, 40 kilo Newton, so required tire pressure is 550 kilopascal and rut depth 50 millimetre or less, characteristics of the sub-grade soil, that is CBR value is equal to 0.5 or undrained shear strength value is 15 kilopascal.

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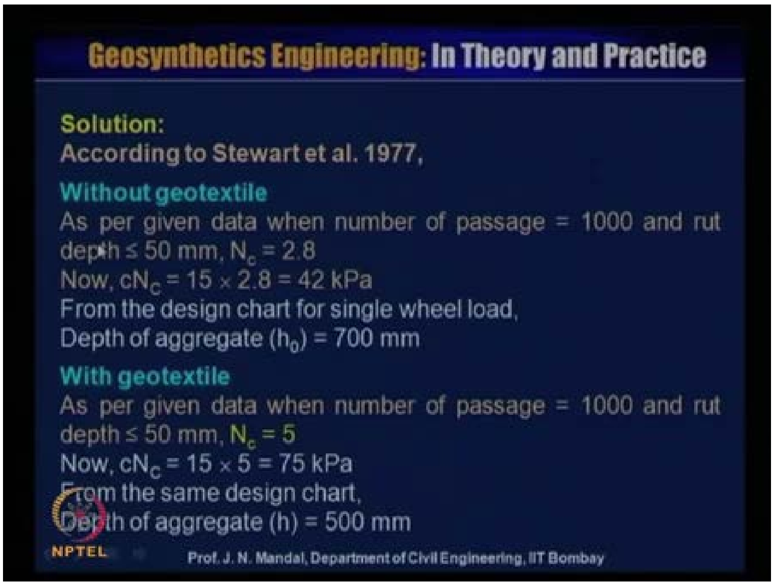

So, solution according to Stewart, 1997 without geotextile as per the given data when the number of the passage 1000 and rut depth less than 50 millimetre, the N c value will be 2.8. You can see here, this is without geotextile and rut depth less than 50, and traffic greater than 1000, so bearing capacity factor in N c is 2.8, so that is why this N c value here is 2.8, number of passage 1000 rut depth less than 50, N c 2.8.

So, C into N c, c is 15 into N c is 2.8, C is 15 is given here undrained shear strength of the soil 15 kilopascal, so C is given 15 and N c is 2.8 that means, this C into N c will be the 42 kilopascal. Now, from the design chart for single wheel load, so you can calculate the 80 that means, you can calculate what will be depth of the aggregate. So, this is the design chart for the single wheel load, where tire pressure is 550 kilopascal, and that what is the C into N c value that means, 42 kilopascal.

So, what should be the N c value here 42, this is about 35, this will be about 42 something and about here and then, for this you have to calculate what is the single wheel load. Because, this wheel load is given is in your problem, it is that given that load value here it is 40, single wheel load 40, so this will be this will be the 40, for this C u into N c value and this is 40, so you can calculate what will be the thickness of the aggregate.

So, this will be about 700, this is between 600 to 800 this will be about 700, so that is why depth of the aggregate h 0 is equal to 700 millimetre. So, C into N c 42 and correspondingly we can calculate for that 40 kilo Newton wheel load, so you can calculate like this C into N c 42, this 42 and then, you can calculate thickness of the this aggregate, so h 0 is equal to 700 millimetre.

Similarly, with geotextile as per given data when number of passage 1000 and rut depth less than equal to 50 millimetre N c is 5, so you can see from this diagram with geotextile rut depth less than 50 millimetre, and traffic is 1000, so bearing capacity factor N c is equal to 5. So, you can write here that N c value is equal to 5, now C into N c, C again is 15, N c is 5, so 75 kilopascal, now from the same design chart, you can calculate what will be the depth of the aggregate.

So, you can see this C into N c is 70, so this C into N c is this is about 75 kilopascal, so this is 75 kilopascal and this is your wheel load and then, you can go horizontally which will touch the y axis somewhere here. So, this will give you in between the 400 to 600 millimetre that means, it will give about may be 500 millimetre, so depth of the aggregate with geotextile is 500 millimetre. So, you can observe that without geotextile your depth of the aggregate is 700 millimetre, so with geotextile the depth of the aggregate is 500 millimetre, so that means you can reduce the thickness of the pavement.

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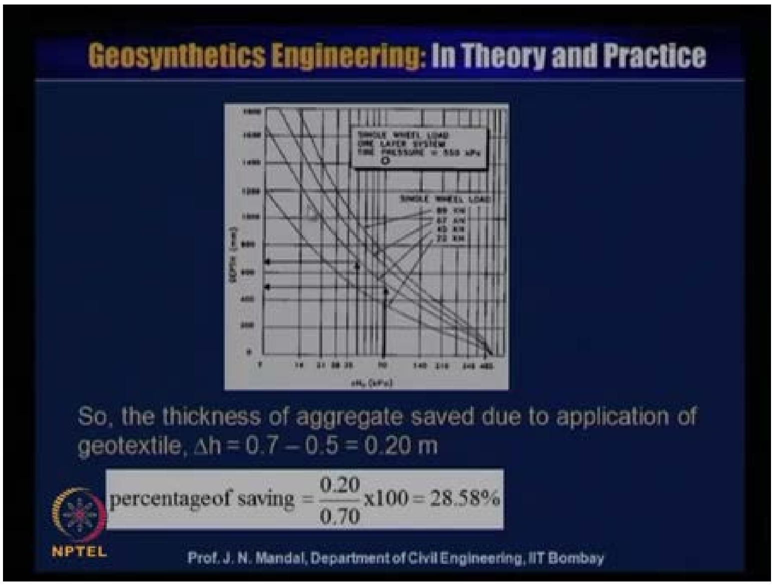

So, thickness of the aggregate saved due to application of geotextile, that is delta h will be equal to 700 millimetre minus 500 millimetre or 0.7 minus 0.5 is equal to 0.20 metre. So, that means, percentage of saving is about 0.2 by 0.7 into 100 that 28.58 percentage, so you are saving about 28, 29 percentage is saving. So, very good amount of aggregate you are saving, when you are using this geosynthetics material as a separation.

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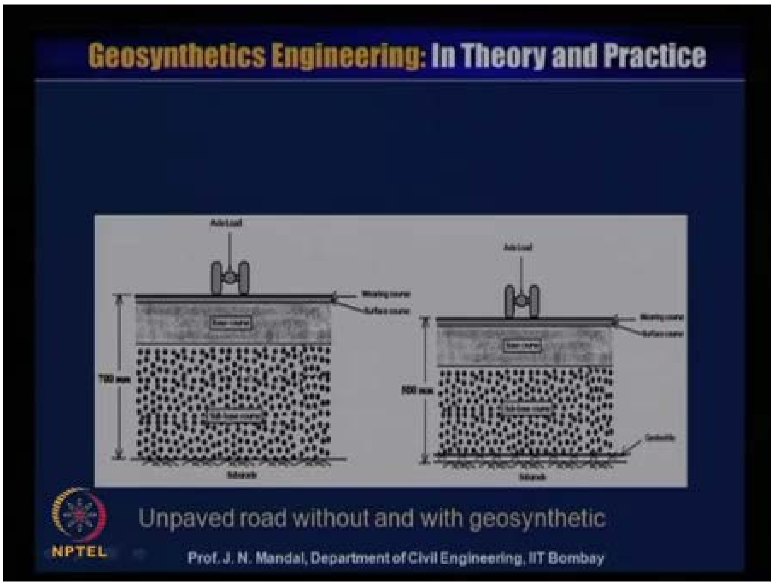

Here, just shows this diagram for the unpaved road without and with geosynthetics road, when the with without geosynthetics this thickness of the pavement is 700 millimetre, and when the geosynthetics is introduced in between the sub-grade and the base layer. Then, the thickness of the pavement is about 500 millimetre, and as usual we use that we know that this is the sub-base core, this is the base core and these are the surface cores and the wearing cores, so according to the IRC code you can select.

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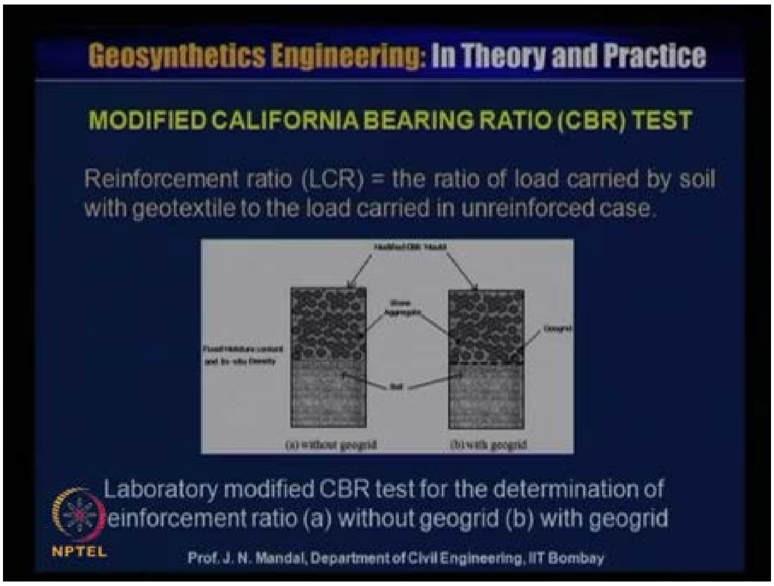

Now, this is modified California bearing ratio test, this we call that reinforcement ratio or LCR, is the ratio of load carried by the soil with geotextile to the load carried in unreinforced case. Here, laboratory modified CBR test for determination of reinforcement ratio without geogrid and with geotextile are shown, this is without geogrid and this is the soil, and this is at a particular moisture content, and the in situ density.

And then, the top of this soil you are placing this aggregate, and the right hand side you have modified the CBR mould, and you are placing the soil at the bottom layer, and the top is the aggregate layer. But, in between the, interface between the soil and aggregate, we are placing one layer of the geosynthetics material, which will act also as a separation. So, here bottom layer also soil, but top layer is the aggregate layer, this you have made in a modified CBR mould. Now, you have to apply the load here, and you measure that some soil what should be their shrinkage limit, liquid limit and the plastic limit, that what will be the moisture content and the in situ density, so what we what we do when we perform the test.

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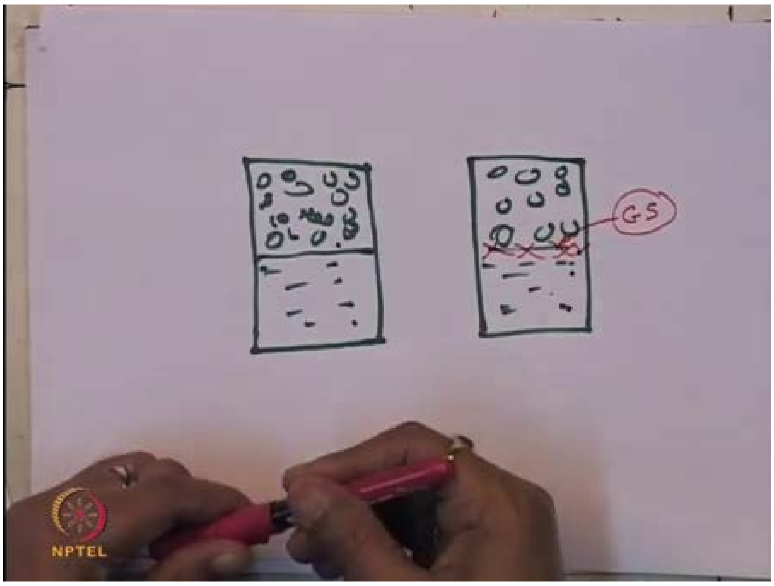

So, let us say this is the mould and the lower part is the soil, and upper part is the aggregate layer, and in case of the reinforcement lower part is the soil and upper part is the aggregate layer. And in between here we are placing this geosynthetics material, now you the soil is at the bottom, aggregate is at the top, so when you apply the load and you measure the what should be the deflection.

So, for a particular moisture content, you measure what should be the deflection in millimetre and correspondingly what should be the reinforcement ratio, one with the different moisture content and you measure the defection. Let us say deflection is 3.3 millimetre, 4 millimetre, 5 millimetre, 6 millimetre and correspondingly what should be the load for the unreinforced case.

Similarly, what should be the load for the reinforced case, so if you take the ratio of the load carried by the soil with geotextile to the load carried in the unreinforced case, will give you that what will be the reinforcement ratio or the LCR. So, you can calculate the LCR value, so for a particular deflection, so you can calculate that what will be the reinforcement ratio value.

So, that what will be the reinforcement ratio value, or it called the LCR also layer coefficient ratio, so this is important to us that what should be the LCR value. So, this value ratio value at each deflection is increases, when the moisture content also is increasing, so from this test you can roughly can calculate that what will be the thickness of the stone aggregate.

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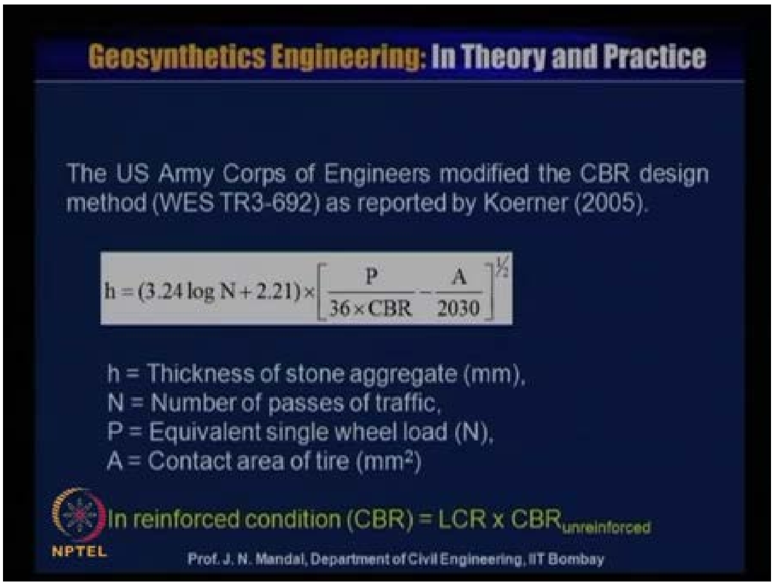

So, this is given by u s army corps of engineer modified the CBR design method, WES TR3-692 as reported by Koerner, 2005, so this is the equation. So, h is equal to 3.24 log N plus 2.21 into P divided by 36 into CBR minus A divided by 2030 whole to the power half, where h is the thickness of the stone aggregate in millimetre. N is the number of the passage of traffic and P is the equivalent single wheel load that is Newton, and A is the contact area of the tire.

Now, only this CBR value will change, when there will be no geotextile material, so you know what will be the CBR value and when there is a reinforcement, then this CBR value will change. So, this CBR value on the higher side with respect to the unreinforced soil, and that is why the thickness of the stone aggregate will reduce, so in the reinforced condition you can see that CBR will be equal to LCR into CBR of unreinforced.

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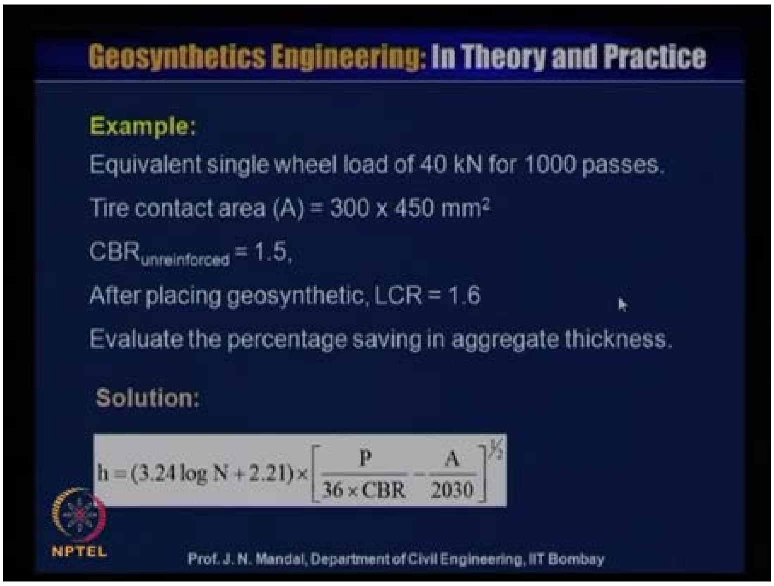

So, we will see some example, so here is one example, so let us say equivalent single wheel load is 50 kilo Newton for 1000 passage, tire contact area A is 300 into 450 millimetre square and CBR in unreinforced is given 1.5. After placing this geosynthetics material you can calculate what is LCR, LCR is equal to 1.6, so you can have that what will be the LCR, what is the CBR relationship.

So, if the CBR for a particular geosynthetics material you can calculate the LCR, I will also say you let around what will be that nature of the curve, and how you can calculate the LCR for the different value of CBR. So, from that design chart also you can calculate that what should be the LCR value for a particular geogrid material, so evaluate the percentage of saving in aggregate thickness. Now, this equation for the determination of the aggregate thickness.

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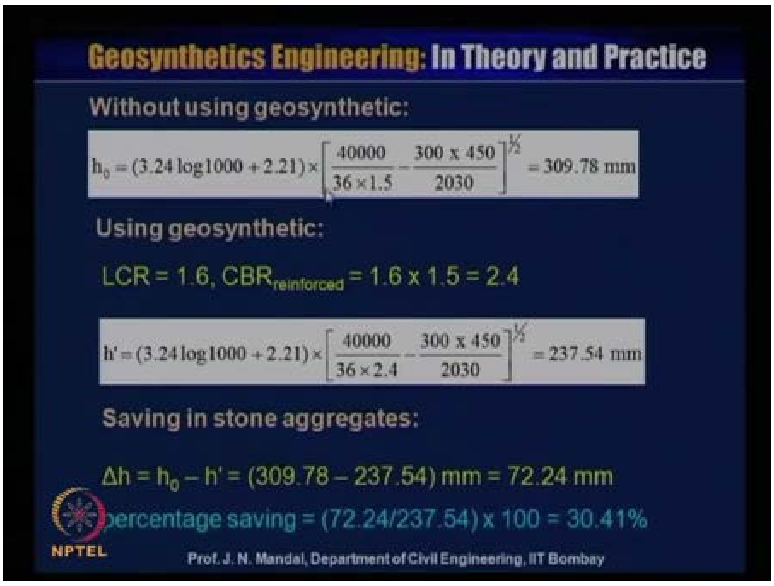

Now, without using geosynthetics material h 0 is equal to 3.24, N value is 1000, that is why it is log of 1000 plus 2.21 and ((Refer Time: 28:49)) this is P and this P is P divided by 36 into this. So, that this is the P is this, this is in terms of this is 40 kilo Newton, so this is a Newton, as I say this equation in terms of the Newton this divided by 36 and this CBR is 1.5. And this is your A, A is this 300 into 450, so this is 300 into 450 this divided by 2030 whole to the power half, so you can obtain h 0 is equal to 309.78 millimetre.

So, using geosynthetics material LCR value is let us say 1.6, so CBR in reinforced will be 1.6 into 1.5 is 2.4, now let us say that with geosynthetics this thickness is h of dash. So, h dash is equal to 3.24 log, this is N 1000, this is plus 2.21, this will be the same as it is, this all same as it is only here this CBR value is change. So, CBR value reinforced case it will be 2.4, so this will be 2.4, instead of 1.5 which was there in the unreinforced case this is 2.4.

So, if you now calculate then you can obtain the h dash value is 237.54, so you see the different between without geosynthetics thickness of the pavement 309.78 millimetre, with geosynthetics thickness of the pavement 237.54 millimetre. So, saving in stone aggregate delta h is equal to h 0 minus h dash is equal to 309.78 minus 237.54 millimetre is equal to 72.24 millimetre.

That means, percentage of saving is equal to 72.24 divided by 237.54 into 100 about 30.41 percentage of saving. So, this is based on the laboratory and the modified that

CBR mould, and this test has been performed this is just for get some idea about the effect of the geosynthetics material, for the pavement design. So, this will give you some rough idea about this laboratory system.

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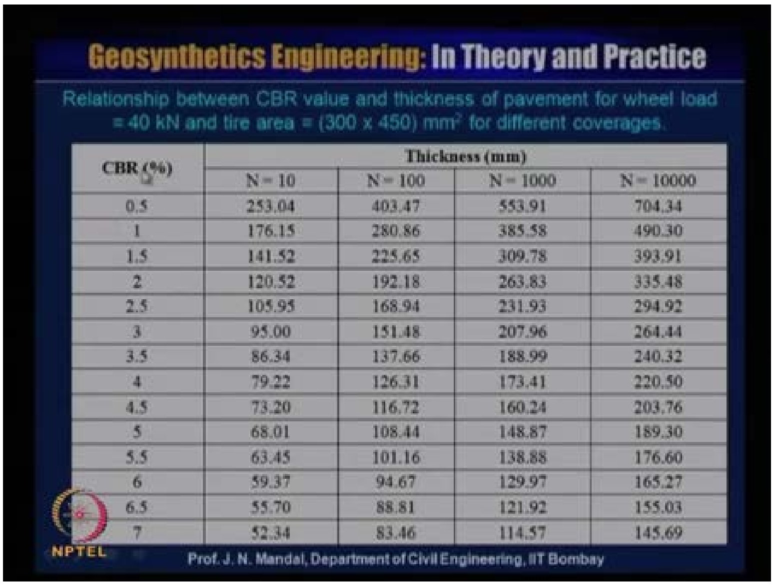

CBR (%)	Thickness (mm)			
	N = 10	N = 100	N = 1000	N = 10000
0.5	253.04	403.47	553.91	704.34
1	176.15	280.86	385.58	490.30
1.5	141.52	225.65	309.78	393.91
2	120.52	192.18	263.83	335.48
2.5	105.95	168.94	231.93	294.92
3	95.00	151.48	207.96	264.44
3.5	86.34	137.66	188.99	240.32
4	79.22	126.31	173.41	220.50
4.5	73.20	116.72	160.24	203.76
5	68.01	108.44	148.87	189.30
5.5	63.45	101.16	138.88	176.60
6	59.37	94.67	129.97	165.27
6.5	55.70	88.81	121.92	155.03
7	52.34	83.46	114.57	145.69

Now this table show the relationship between CBR value, and the thickness of the pavement of wheel load is 40 kilo Newton, area is the same 300 by 450 millimetre square for different coverage. So, here you can see CBR value different percentage 0.5, 1, 1.52 these are all very poor soil and N value 10, 100, 1000 and the 10000, for any value of the CBR and for the number of the passage, so you can directly determine what should be the thickness of the pavement.

So, you can directly determine from this table, so this is 40 kilo Newton I say the wheel load tire pressure is the same, and let us say if it is a CBR value 1.5, and this value N value is 1000, you can see that thickness of the pavement is 309.78. ((Refer Time: 32:35)) you can see approximately you can have this same value 309.78, and if this uses pavement thickness about 2.4 what we have obtained in between 2.4, let us say 2.5. And this N value is about 1000, so we can see that thickness of the pavement will be 231.93, so you can see 237.54. Because here it is little 2.4 little bit more, so this will be approximately you can give some idea that what will be the thickness of the pavement with you.

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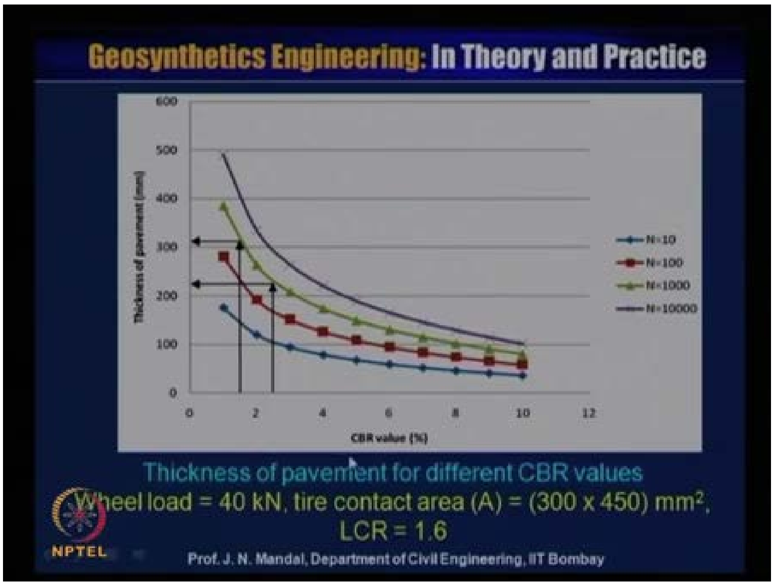

We can draw the curve between the thickness of the pavement, and for different value of CBR and under the N value of 10 and 100 and 1000 and the 10000, so from this chart also, if you what is wheel load that is 40 kilo Newton, contact tire contact area a 300 into 450 millimetre square. And NCR 1.5 for any value of CBR you can also directly calculate that what will be the thickness of the pavement, you can see for the 1.5 or whatever this is about 300 something. For this two point ((Refer Time: 34:00)) value this will give about 237, so also this some design chart has been made.

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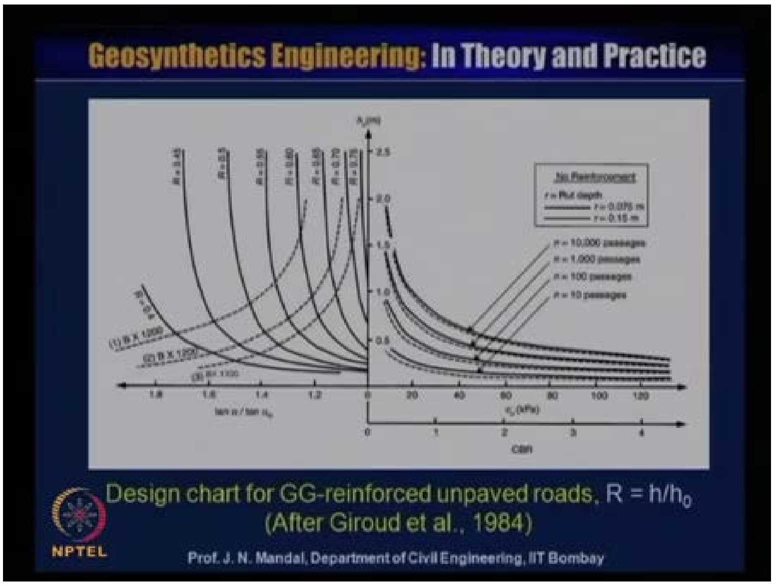

Now, so far we would talk about with geosynthetics some material, how to determine the thickness of the pavement, and here the design chart for geogrid reinforced unpaved road. So, if you take the geogrid reinforced unpaved road, how you can calculate the thickness of the pavement from this design chart. Now, for this design chart, you should know how to use this chart, and this design chart has a standard axial load and that is equal to 80 kilo Newton.

And number of the vehicle also passage from 10, 100, 1000, and the 10000 passage, I will just show you from here, so this is the design chart and this is the standard axial load, I say that 80 kilo Newton. And the number of vehicle passage is n is equal to 10 passage, N is equal to 100 passage, this N is equal to 1000 passage and then N is equal to 10000, passage and this right hand side of the chart is for the unreinforced case. That means, without geotextile, there is no reinforcement and there are you can see that one form and another is the dotted line.

The form line indicate the rut depth, that is r designated as r, if the rut depth is 0.075 meter, then you can use this form line, and if it is the rut depth is 0.15 meter, then you can use the dotted line. And this x axis show that, what will be the undrained shear strength of the soil C u in kilopascal or the California bearing ratio, that is CBR. So, from this ((Refer Time: 36:27)) curve, you can calculate what will be the thickness of the pavement h 0 without geosynthetics. That means, if either the C u or the CBR value and if you know what will be the number of the passage, then you can calculate that what will be the thickness without geosynthetics material for unpaved road case.

So, next in the left hand side you can see that this is r, r is nothing but, h by h 0, h is equal to the thickness of the unpaved road with geogrid reinforcement, and h 0 is the thickness of the unpaved road without geosynthetics material. So, r is the ratio of thickness of the pavement with geogrid reinforcement, and the thickness of the pavement without geogrid reinforcement, so this left hand side is for the thickness for geogrid material.

So, from the left hand side you can calculate that what should be the r value, so this is kind of the soil, it may be the very soft or the compressible foundation soil for unpaved aggregate. And that what is the mechanism of reinforcement are increased the soil strength or enhance the load sparing, and membrane supporting are the control the rutting, and this kind of the design chart is recommended for use. And you can find out also the difference what will be the required thickness of the stone base, which you can compare with the cost of the installed geogrid material.

So, when you will use that curve on the left hand side, so what will be the thickness of the unreinforced case and then, you extend it and you select the geogrid material, this is the different geogrid material, so you can select the geogrid material. So, then you can calculate what will be the value of r, if this line touches in between r is equal to 0.5 to r is equal to 0.5, then you can interpolate and can calculate what will be the value of r. So, if that what will be the value of r that means, r is the ratio of h by h 0, so h 0 is known to you, r is known to you. So, you can calculate what should be the thickness of the pavement with geogrid material.

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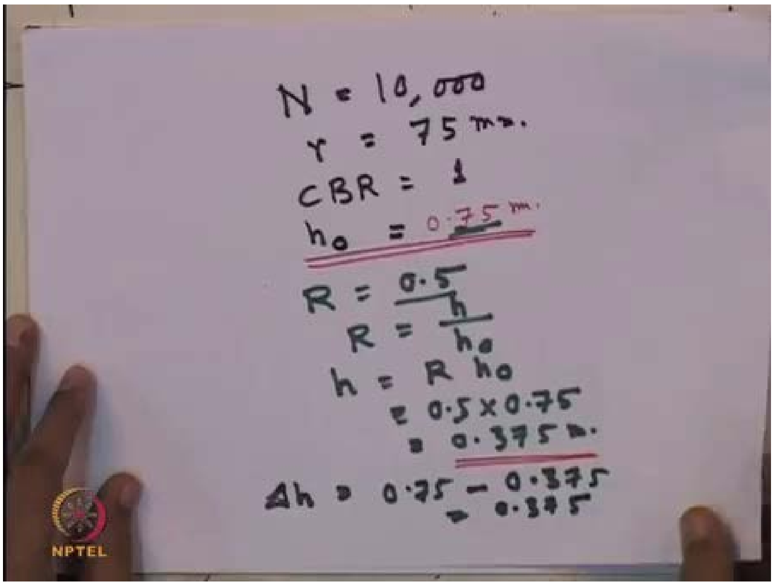

So, I am giving one of the example that for example, that N value we are considering 10000 and rut depth is equal to 75 millimetre and CBR is equal to 1, so you calculate what will be the h 0. So, when that N value is the 10000 that means, you can use ((Refer Time: 40:08)) this chart that CBR value is 1, this is the CBR value is 1, so if CBR value is 1 and number of passage is 10000. Then, CBR 1 and number of passage is you can go vertically up and number of passage is 10000, and r is equal to 75 millimetre.

So, you can calculate that what will be the thickness of the pavement without geotextile, let us say this value h 0 value is somewhat 0.75 in between 0.5 to 1.75, so h 0 is equal to we obtain 0.75 meter without geosynthetics material. (Refer Time: 41:10) Now, now we select the some of the geogrid material, let us say we select this geogrid material, so you can proceed further and let us say we have selected this is the geogrid material B x 1200. So, then it will meet at this r, r is equal to 0.50 that means, we know what is r for this geogrid material.

So, we can write that r is equal to 0.5, so we know that r is equal to h divided by h of 0, so h will be equal to r into h of 0, what is r, r we have obtained 0.5, so this will be 0.5 into and h 0 is 0.75, so this is 0.75, so this will give you about 0.375 metre. So, with geogrid, so thickness of the pavement is 0.375, for example if I say that, if the curve somewhere here, then you can interpret between 0.45 to 0.5. So, what will be the aggregate shape, so aggregate shape delta of h will be equal to 0.7580 minus 0.375 that means, this will be the 0.375 that means, you can shape almost the 50 percentage, so this way you can use this also the design chart. Next I will explain design of pavement, unreinforced and reinforced condition.

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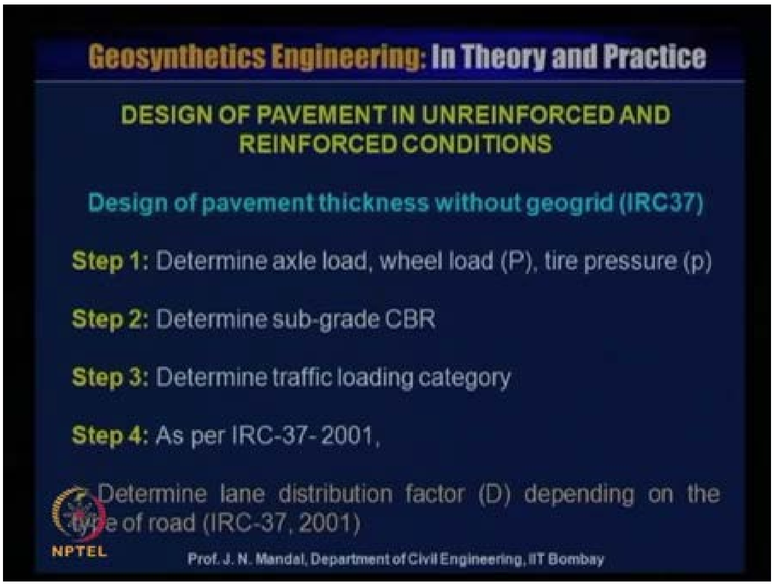

Design of pavement thickness without geogrid as per IRC 37, step 1 determine the axle load wheel P and tire pressure P, step 2 determine the sub-grade CBR value, step 3 determine traffic loading category. And step 4 as per IRC-37-2001, determine the lane distribution factor D depending upon the type of the road as per IRC 37 to 001

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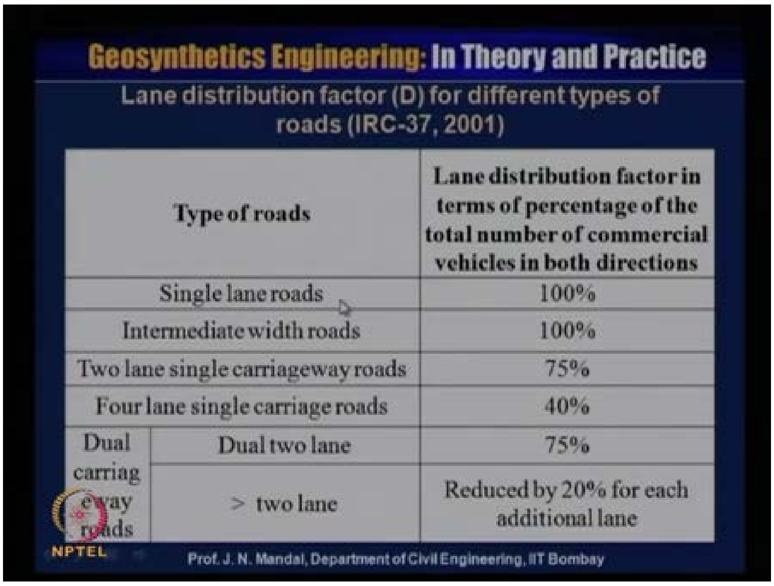

So, this is the length distribution factor D for different types of the road as per IRC-37-2001, now you can see that type of the road, it may be single lane road or intermediate width road, two lane single carry way road, four length single carriage load, dual carriage load dual two lane, and greater than two lane. What will be the lane distribution factor in terms of the percentage of the total number of commercial vehicle, in both the direction, whether it is a single load, it is a 100 percent intermediate with road.

Or the two lane carriage road is 75 percent, four lane carriage road 40 percent and dual lane is 75 percent and greater than reduced by 20 percent, for each additional road, this is code has been specified to calculate that what should be the value of D. So, D you can calculate that what percentage, and that depend upon the what will be the type of the road for example, that if we consider two lane single carriage way load. So, then we will say that commercial vehicle for both direction, this is the load distribution factor that mean capital D will be equal to 75 percentage. So, we will use this table based on the type of road.

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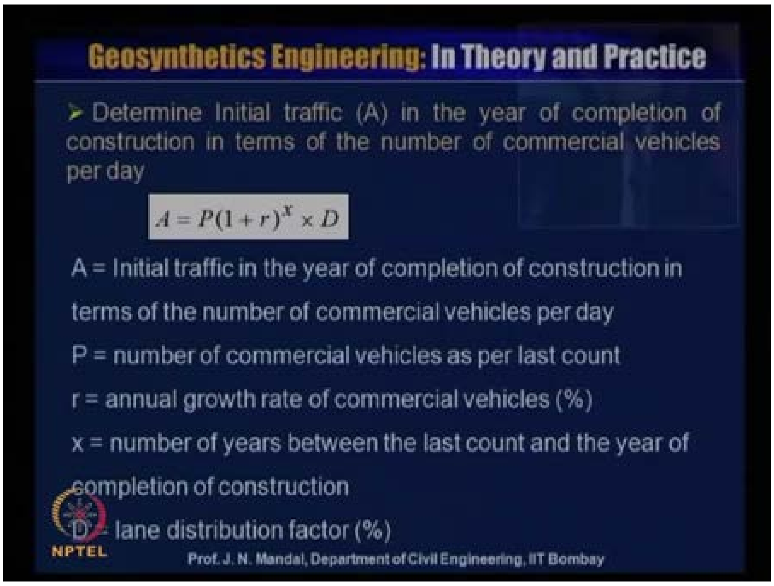

Next determine the initial traffic that means, A in the year of completion of the construction in terms of the number of commercial vehicle per day. So, this is the equation given by the code A is equal to P into 1 plus r whole to the power x into D, A is the initial traffic in the year of completion of construction, in terms of the number of the commercial vehicle per day.

So, you will be knowing what will be the commercial vehicle per day you have to calculate, so P is the number of the commercial vehicle as per the last count, r is equal to annual growth rate of commercial vehicle in percentage. X is equal to number of the year between the last count and the year of completion of the construction, and D is the lane distribution factor in percentage, and this lane distribution factor you can determine from the table.

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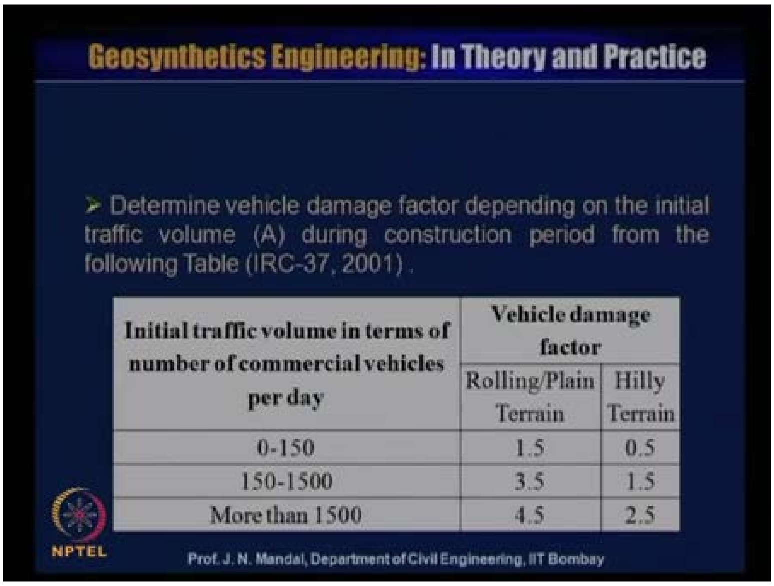

Initial traffic volume in terms of number of commercial vehicles per day	Vehicle damage factor	
	Rolling/Plain Terrain	Hilly Terrain
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

And determine vehicle damage factor depending on the initial traffic volume A, so during the construction period from this following table as per IRC-37-2001. So, you can see that initial traffic volume in terms of the number of commercial vehicle per day, it is called CVD, if it is a 0 to 150 and vehicle damage factor, it is a rolling or plain terrain or hilly terrain. So, if it is lies between 0 to 150, so if it is a rolling and plain this vehicle damage factor you have to take 1.5, if it is a hilly terrain, this vehicle damage factor is 0.5. If this 150 to 1500, then this vehicle damage factor is 3.5 and hilly terrain 1.5, similarly if it is a more than 1500, then this vehicle damage factor 4.5 and this hilly terrain is 2.5.

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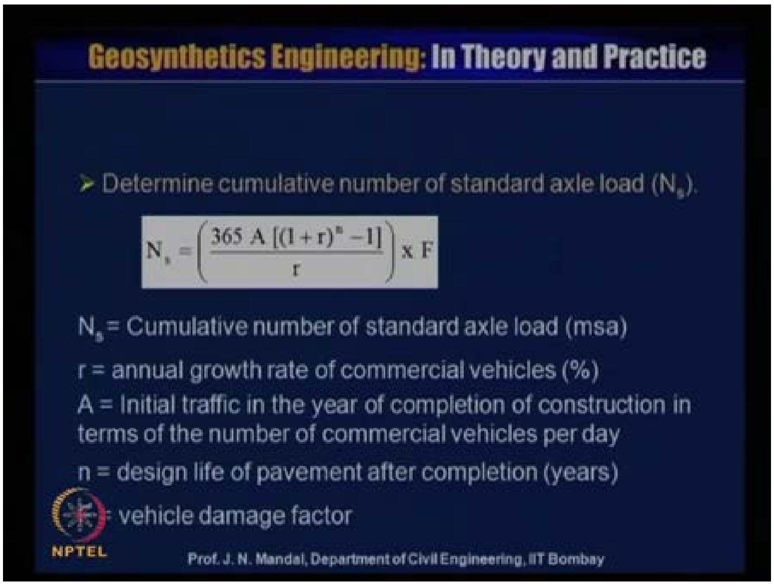

Now, determine the cumulative number of standard axle load N s, so you have to what will be the standard axle load with this equation, N s is equal to 365 A into 1 plus r to the power n minus 1 divided by r into F, where N s is the cumulative number of standard axle load, that is msa. And that A is equal to initial traffic in the year of completion of the construction, in terms of the commercial vehicle per day.

And r is the your annual growth rate of commercial vehicle in percentage, and n is the design of the pavement after completion or year and F is equal to vehicle damage factor. So, you can calculate the vehicle damage factor from this ((Refer Time: 48:55)), depending upon the what should be the commercial vehicle per day passing, so you can calculate the damage factor, that means F.

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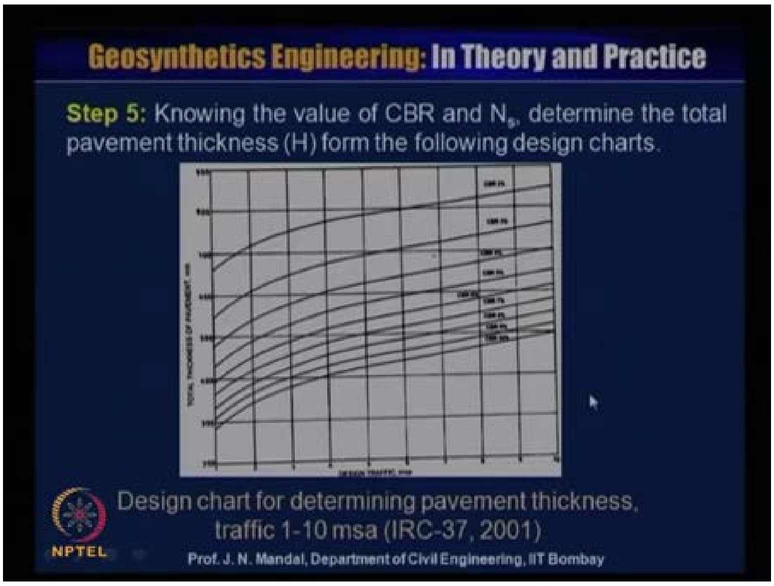

Now, step 5 knowing the value of CBR and N s, determine the total pavement thickness h from the following design chart, so this design chart determine what will be the pavement thickness. So, it give that relationship between that, what should be the thickness of the pavement, there is a design traffic and this traffic lies between 1 to 10 msa, you can see it start from the 1 to 10 msa. So, this design chart is only for 1 to 10 msa, and this is the different value of CBR California bearing ratio value.

So, it may be 2 percent, 5 percent, 7 percent 8 percent ten percent, so knowing that what would be the traffic that means, which may lie between 1 to 10 msa, so what is CBR value, then you can calculate what will be the thickness of the pavement. These all we are talking this design chart based on the IRC code specification and this is mainly for the unreinforced soil, so there is no geotextile or geogrid material. So, this design chart show that how to calculate the thickness of the pavement, without geotextile material when the traffic is 1 to 10 msa and also for various value of the CBR.

((Refer Time: 50:48))Similarly, this is another design chart for determination of the pavement thickness, this is the design traffic, now here design traffic has increased from 10 to 150 msa. So, if the 10 to 150 msa for the different value of CBR you can also calculate what will be the thickness of the pavement. So, there are two chart one is lies between 1 to 10 msa, then this design chart is lies between 10 to 150 msa, so knowing that what will be the design traffic in terms of msa and knowing the value of CBR, you can calculate what will be the thickness of the pavement.

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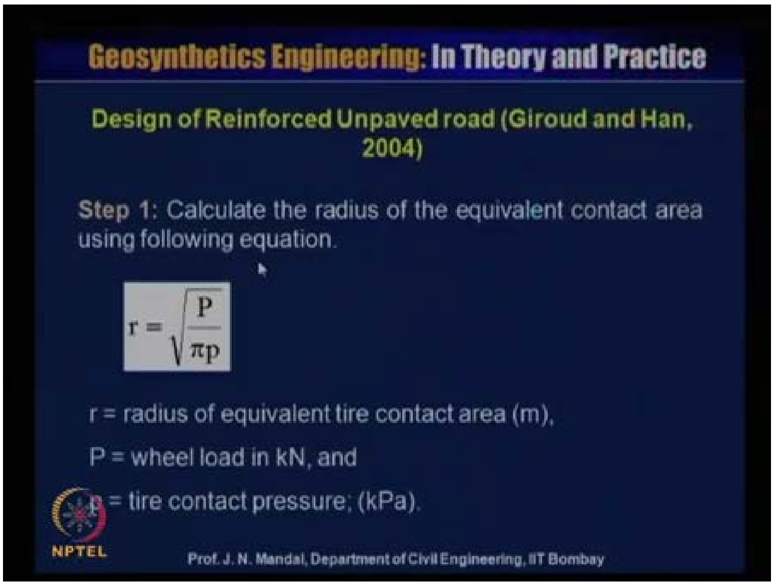

So, this way you can calculate that what will be the thickness of the pavement for unreinforced cases, so follow this design chart as per IRC, I say this is for the unreinforced soil, there is no design for IRC for the inclusion of the geosynthetics material design chart. But, we will show you some of the design chart and how we can calculate the what will be the thickness of the pavement, without and with geosynthetics material.

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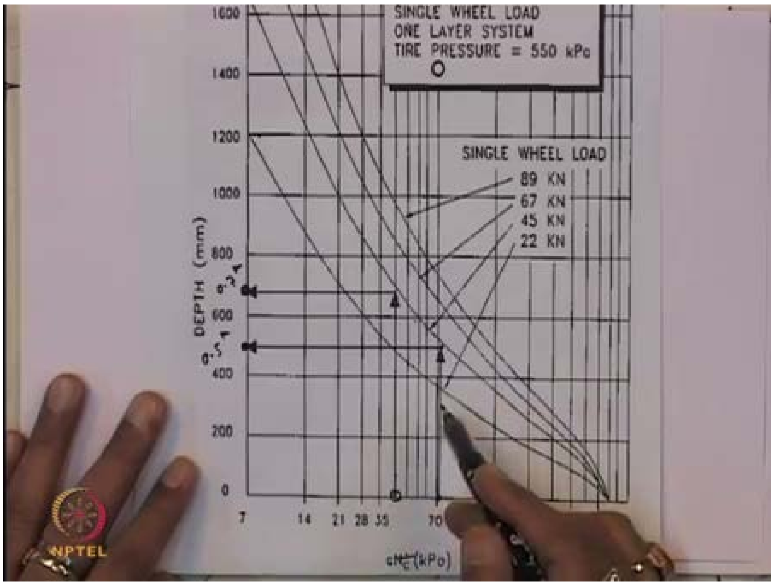

So, here is the design chart for the calculation, for the thickness of the aggregate, this is single wheel load one layer system tire pressure 550 kilopascal, and this is under the various load 22 kilo Newton, 45 kilo Newton, 67 kilo Newton and 89 kilo Newton this is single wheel load. In our problem we have considered it only single wheel load is 40 kilo Newton that means, we will consider in between these two load 22 kilo Newton and the 45 kilo Newton.

Now, we calculate the C into N c value, the undrained shear strain and we know the N c, N c for the unreinforced case is 2.8 and c is 15. So, C into N c will be equal to 42 kilopascal. So, then here you can see that C into N c about 42 kilopascal and then, correspondingly you can move up, and for the 40 wheel load, you move horizontally and this is the depth. Or this is the thickness of the aggregate without geosynthetics material, which will be about 0.7 metre or 700 millimetre, so this way we can calculate what will be the thickness of the pavement for unreinforced case.

Now, I will discuss further reinforced case for the reinforced case this N c value is 5 and C value is 50, so C into N c will be 75 kilopascal, so it will be somewhere here 75 kilopascal. So, you move up and this is 50 that is wheel load, then it move to the horizontally which will touch this y axis, at the depth of 0.5 meter or 500 millimetre, so this will give about 0.5 metre, this will give about 0.7 metre. So, this way we determine what should be the thickness of the pavement with geosynthetics, so thickness of the pavement with geosynthetics is 0.5 metre. So, what will be the thickness of aggregate shape, due to the application of geotextile that is delta h will be equal to 0.7 minus 0.5 that means, 0.20 metre. So, percentage of saving would be equal to 0.20 by 0.70 into 100 that means, about 28.58 percentage.

Thank you very much, if you have any question.