Geosynthetics Engineering: In Theory and Practices
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Module - 3
Lecture -12
Geosynthetic Properties and Test Methods

Welcome to lecture 12, 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, now begin module number 3 lecture 12 Geosynthetic Properties and Test Method.

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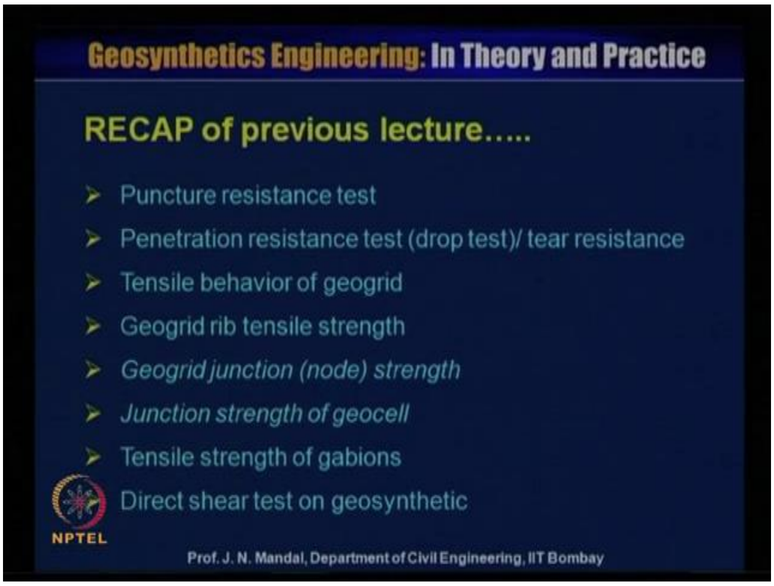

Recap of previous lecture, we have covered puncture resistance test, penetration resistance test or drop test or tear resistance, tensile behavior of geogrid material, geogrid rib tensile strength, geogrid junction or node strength, junction strength of geocell, tensile strength of gabion, and direct shear test on geosynthetics.

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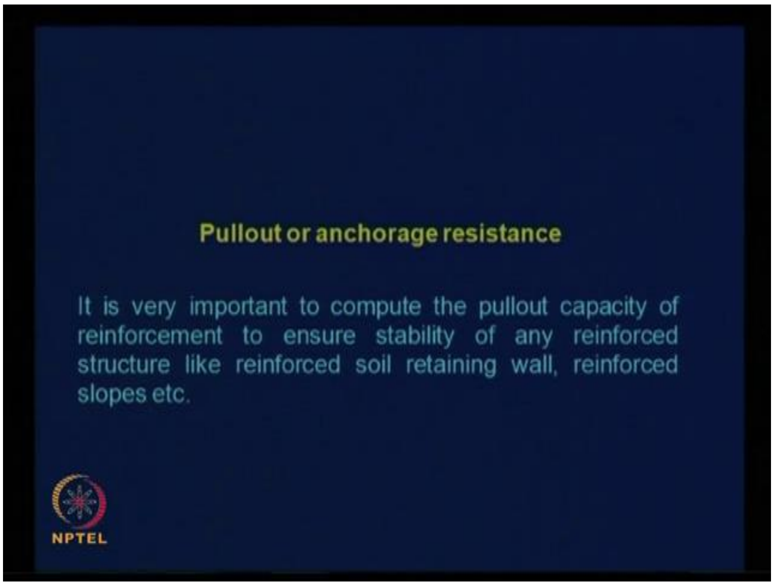

Now, we will discuss the pullout or anchorage resistant, it is very important to compute the pullout capacity of reinforcement to ensure stability of any reinforced structure like reinforced soil retaining wall, reinforced slope etcetera. Now, in case of pullout test two basic mechanism are involved to mobilize or transfer the pullout resistance between soil and geosynthetics.

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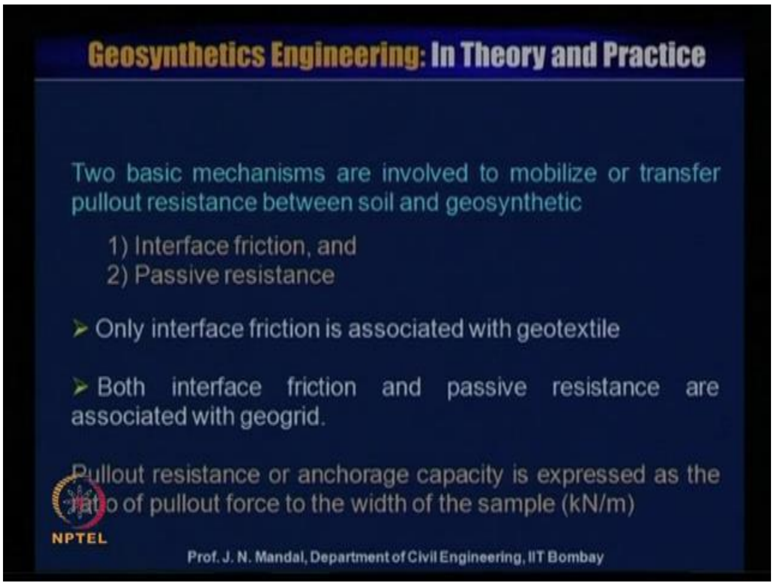

One interface friction and other passive resistance, only interface friction is associated with geotextile or metallic strip or ((Refer Time: 02:50)) or friction time etcetera, both interface friction and passive resistance are associated with geogrid. Pullout resistance and anchorage capacity is expressed as the ratio of pullout force to the width of the sample that is kilonewton per meter.

Now, I will discuss what is interface friction? And what is passive resistance for example, if this is one layer of the soil and then you place this any metallic reinforcement, and then you place another layer of the soil. And then you are pulling you are applying some kind of load, you are putting some applied some load and then you are pulling this pulling, so this is pullout test.

So, you what is happening and this also may happen in case of the metallic strip like this or you can also conduct the test like geogrid material also, the soil is stopped in the bottom and you apply load and then you have pulled it out. So, if it is a metallic strip or it is a kind of woven or the non woven geotextile like this, so there will be a development of friction and how the friction develop.

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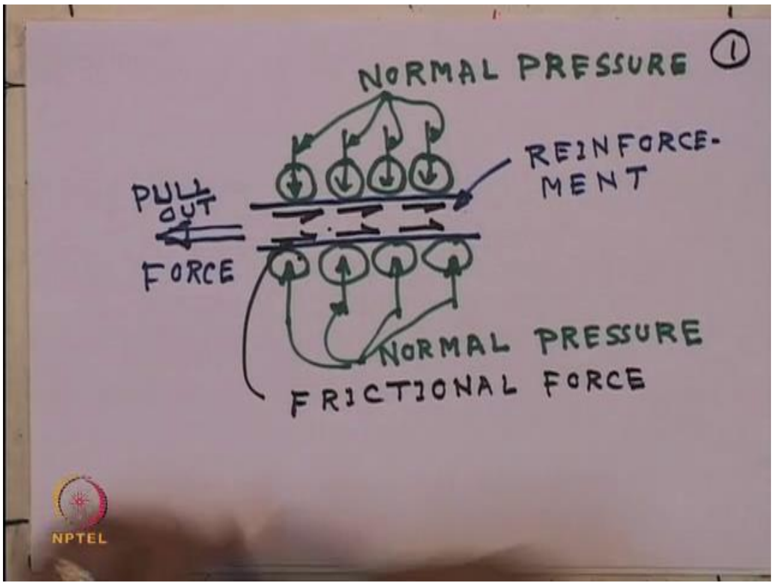

So, let us consider the metallic plate like this, and soil is at the top and the bottom, and this is the normal pressure is acting and this is the normal pressure. So, you can say this is normal pressure all are normal pressure, these are all normal pressure similarly normal pressure, this is all normal pressure, and this is the reinforcement. And this reinforcement may be steel strip it may be the steel strip or it may be the polymer fabric or it may be the or it may be any plastic strip, and then you have pulled it out this is pullout force.

If this is the reinforcement and normal pressure is applied here and then you pulled it out, if you pulled it out then there will be the development of frictional force, this is frictional force. So, this is the frictional force will developed, so this what we call frictional force, so you can see that how the frictional stress transfer between the soil and the reinforcement. Now, this friction; that means, stresses are transferred from soil to the reinforcement by shear along the interface, so you can see that how the friction force is developed between the soil and this reinforcement. Now, this is particularly in case of any metallic strip or any or any plastic strip etcetera.

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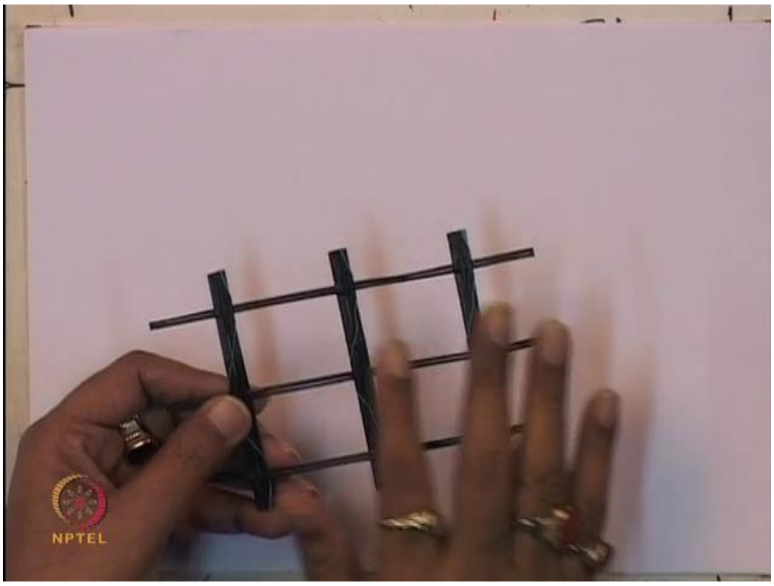

Now, second part is the passive resistance, so for example, that this is a geogrid material, you can see that if you pulled it out there will be a development of frictional resistance and as well as passive resistance here. So, I am just showing this how this development occur that frictional resistance and passive resistance.

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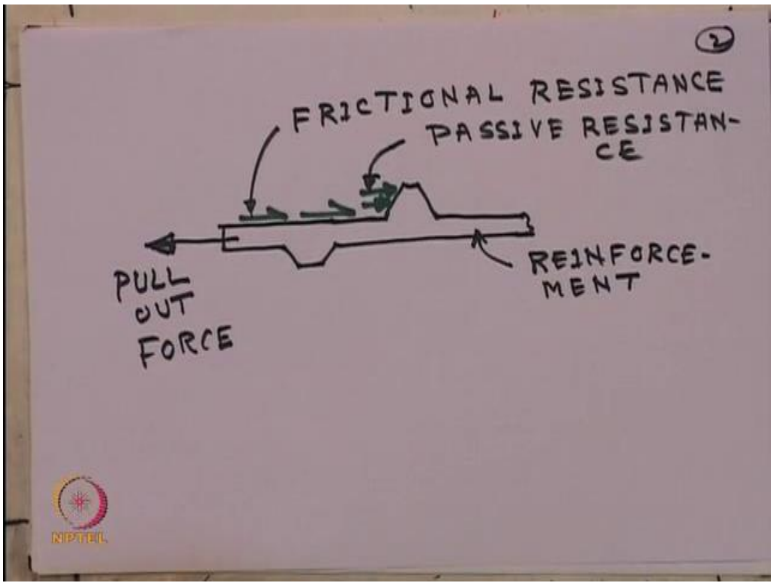

Let us consider this is a kind of the material and like this, let us say it is this like this and you have pulled out, this is pullout force or you can say anchorage. So, this is pullout force, so you can see here there will be a development of frictional resistance, this is frictional resistance, but this portion there will be a development of passive resistance. So, you can see in case of the geogrid material there will be a development of this is what you call frictional resistance, and as well as there will be a development of passive resistance.

So, you can see in case of the geogrid resistance, when we pulled it out due to some applied load, so there will be the frictional resistance developed between soil and this reinforcement material. So, this is the reinforcing material, basically this is the reinforcement material it may be geogrid, this is reinforcement, so when it is pulled it out this frictional resistance and the passive resistance. So, every geogrid material also has a longitudinal direction and also transverse direction, so let us draw a geogrid material say it is like this.

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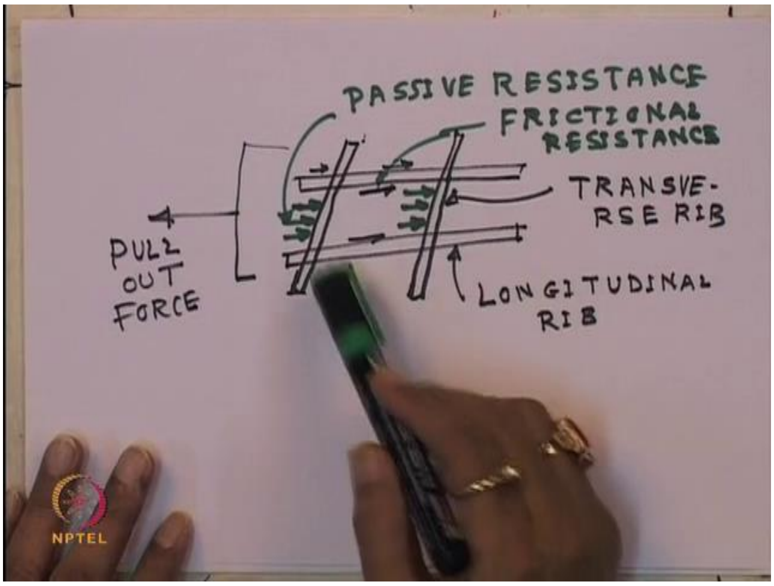

And one thing you are you are putting pullout force and geogrid material has a transverse rib and also longitudinal rib, so this is the transverse rib and also longitudinal rib. Now, due to the pulled out there will be a development of the friction and as well as the passive resistance, you can see there is a development of passive resistance here, also there will be the development of friction. So, you can see also here also friction, here also friction, so these are the frictional force and these are the passive resistance.

So, this is the passive resistance and these are the frictional this is resistance, so here you are showing that soil passive that mean bearing resistance of reinforcement surface. So, passive resistance in stresses are transferred from soil to the reinforcement by bearing between the two transverse element against this soil. So, when you pulled up the material most of the part of the load taken care by the passive resistance or what you saw called the bearing resistance, rather than the frictional resistance in case of the geogrid material.

So, now you have some idea about what is interface friction and what is passive resistance and what kind of the material, where you can the perform the test for the interface friction as well as the passive resistance.

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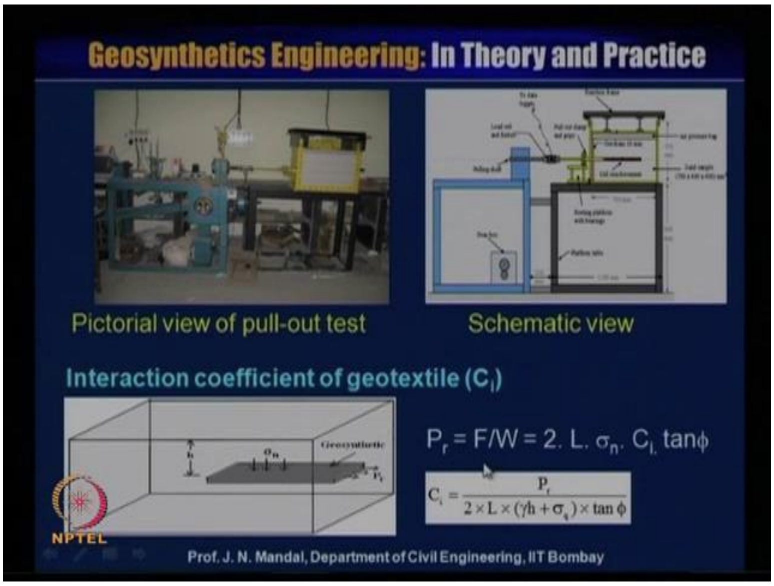

Now, I will show that some pictorial view of the pullout test and this is the schematic diagram, you can see that here is a geogrid kind of reinforcement which is pulled it out. And on the top and the bottom top on the top of this soil you are provided with the rubber, a kind of the balloon on the top, it is a rubber this air pump is tightening with the pump in the rubber.

And then you are applying the load because if we provided with the a kind of the air passage bag then the load will be distributed uniformly, so that is why the reason this is very important that you should provide proper kind of the air passage back on the top of this soil. And also in this back, in the front this back you can provide with a kind of the geofoam material because there is a possibility of development of any earth pressure. So, if you can place a very thin layer of the geofoam material it can reduce the lateral pressure, that way you can perform the proper kind of the pullout test.

So, in case of the pullout test very important is that interaction coefficient of geotextile material, which is denoted as C of i for example, that this is the geosynthetics material and this is the P r and this is the normal load is sigma n. So, you have to calculate what will be the P of r pullout force that is what should be the pullout force, if that pullout force is the F, and if you know what should be the width of the sample, so you can calculate what will be the P of r.

You can see that you can determine what will be the P of r, so this P r is equal to 2 into l into sigma n into C i into tan phi, so C i into tan phi is like a tan delta and sigma n is the normal space. So, if the gamma is the unit weight of the soil here, and h is the height from the geosynthetic material to the top of the soil. So, then you can determine what is sigma of n; that means, this sigma n is equal to gamma into h, and there will be a surcharge load and let us say that surcharge load into sigma of q. So, you can write sigma n is equal to gamma into h plus surcharge load is sigma q.

Now, why it is 2 because the shear stress has acting at the top and bottom of the geosynthetics material, that is why 2 and this is the length embedded length, so 2 into l into gamma h into sigma q into tan of phi. So, C i can be determined P r divided by 2 into l into gamma h plus sigma q into tan phi, so this is phi is known to you, so you can calculate this what is C of i interaction coefficient of geotextile material.

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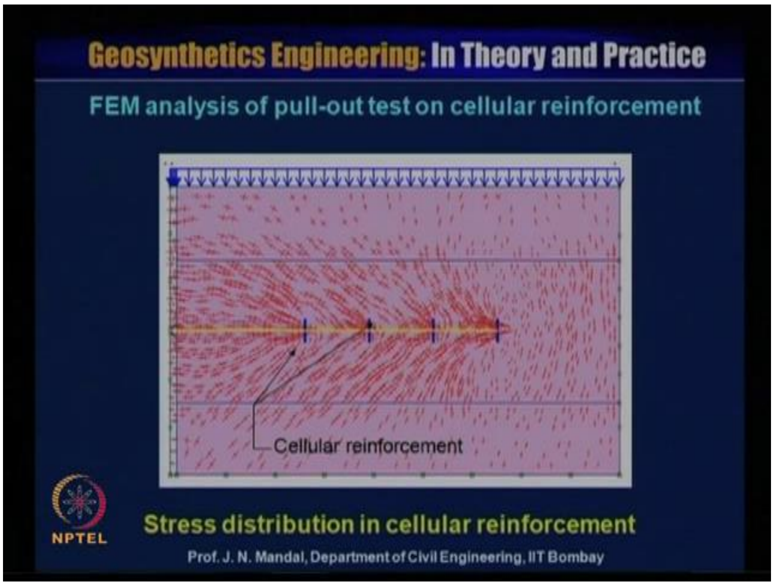

So, this is another F E M analysis of pullout test on cellular reinforcement, here we have considered a kind of the cellular reinforcement, so cellular reinforcement what is cellular reinforcement.

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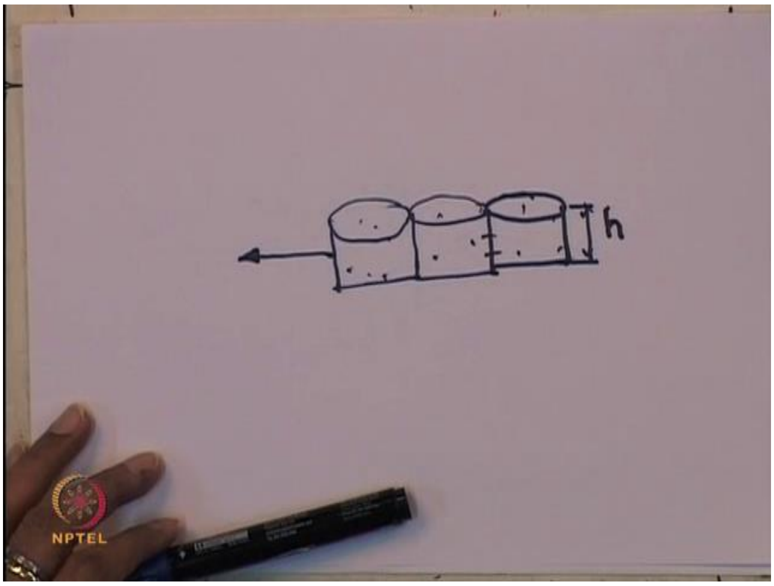

So, it is a made of plastic, it is a bottle it may be hexagonal it may be wave, so this and this and then connected with the another cellular element it can be connected like that, you can also produce a kind of the cellular reinforcement. This is a very good confining effect, and then filled up with the soil and then you can pulled it out because it gives the very good confinement effect also.

Also we will determine what will be the height you can optimize, and you can place this kind of a cellular reinforcement for the construction of the wall at a particular spacing, then we can optimize and can determine what will be the height, and what will be the spacing.

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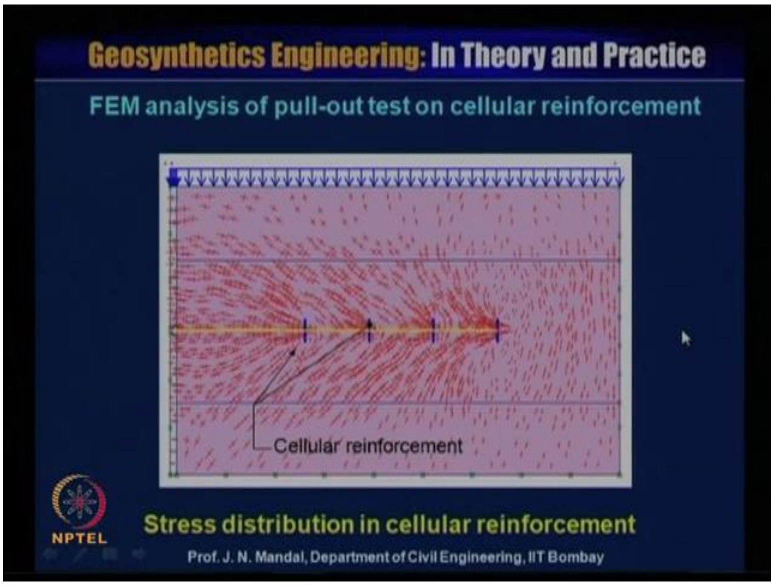

And how we can optimize that also we will focus here, one of the student research called doctor have carried out some test on the cellular reinforcement, you can see that when it is pulled it out. Then you can see how the distribution of the stress is here, this is the stress distribution in a cellular reinforcement and he has conducted the finite element analysis or pullout test on cellular reinforcement.

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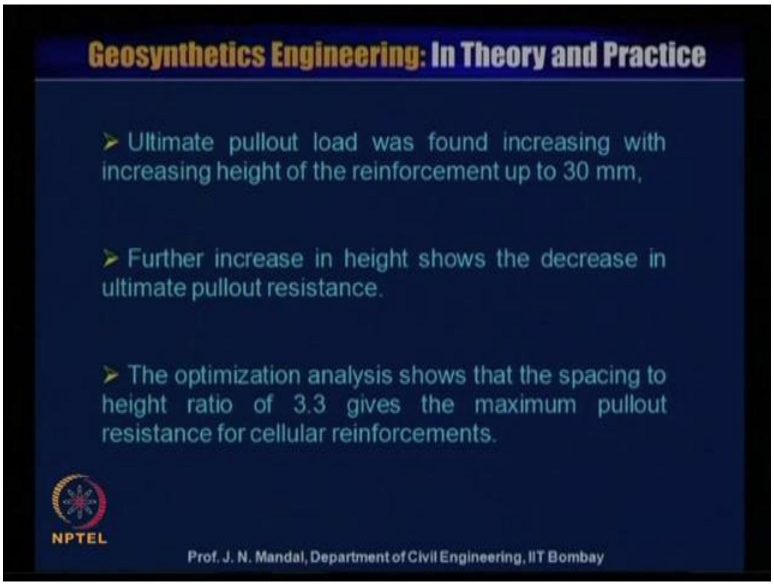

Now, ultimate pullout load was found increasing with the increase of the height of the reinforcement up to 30 millimeter, further increase in the height shows the decrease in the ultimate pullout resistance. So, optimization analysis shows that the spacing to the height ratio of 3.3 gives the maximum pullout resistance of cellular reinforcement, so you can have the idea that what optimize, so height to the spacing to height ratio would be 3.3.

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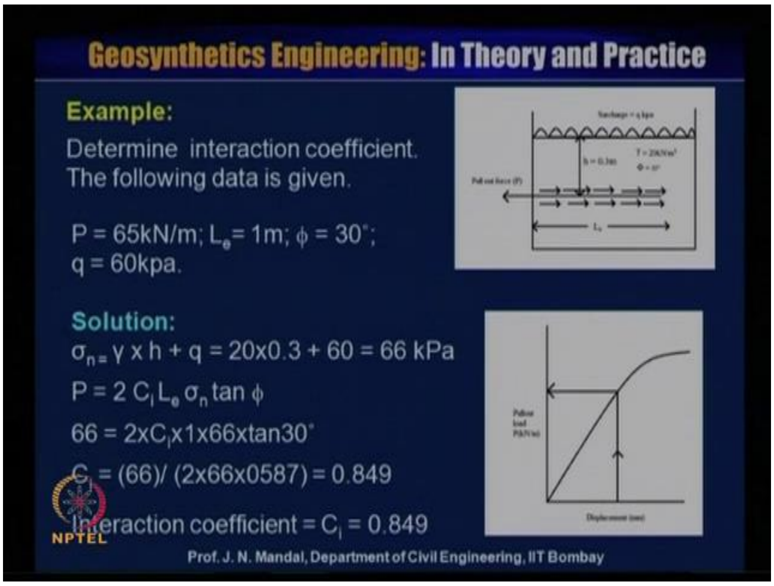

Now, we are giving one example, so you have to determine what will be the interaction coefficient; that means, C i the following data is given P is 65 kilonewton per meter L e is 1 meter phi is 30 degree q is 60 kilopascal. You can see here is pullout P value is given and this is the reinforcement, this length is equal to L of e and this is the height, height is about 0.3 meter and gamma unit weight of soil is 30 kilonewton per meter cube and phi is equal to 30degree and you put something such as pressure is q, and such as pressure q is given 60 kilopascal, height is given that is 0.3 meter.

So, what will be the load sigma h it is acting here, the sigma h is equal to gamma into h gamma is known that is your 20 h is known that is 0.3 plus surcharge load q, q is given 60, so if you calculate you can determine what is sigma n is equal to 66 kilopascal. Now, we know the equation P is equal to C i L e sigma n tan phi, so P is given 65 kilonewton per meter 2 into C i into L e is 1 meter consider 1 meter into sigma n into tan phi sigma n is equal to 66 kilopascal and tan phi is equal to 30 degree.

So, you can calculate the C i, C i is equal to 66 divided by 2 into 66 into 0.587 is equal to 0.849, so interaction coefficient C i is 0.849, this parameter is very important when you will design for any mechanically stabilized reinforced soil structure or the, so stability problem.

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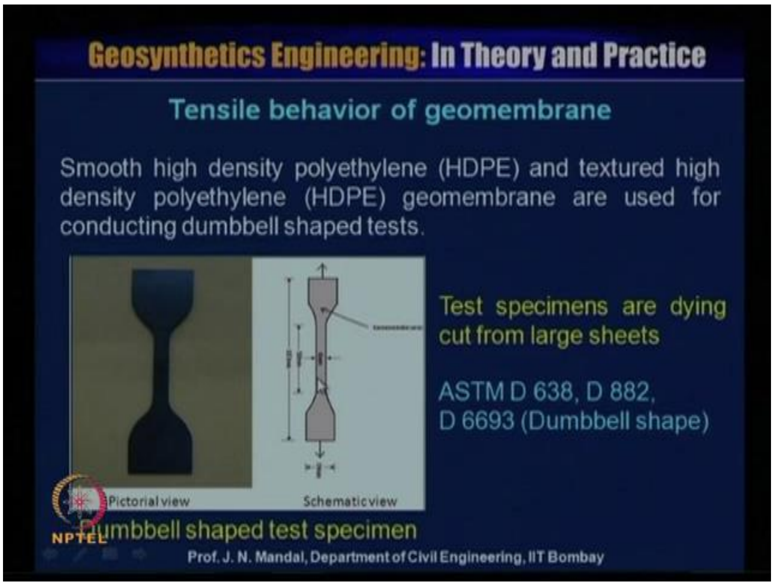

Next we discuss the tensile behavior of geomembrane, so you know that geomembrane is the impermeable material, it is like a rubber and you have a smooth high density polyethylene, which you call H D P E and textured high density polyethylene and geomembrane are also used for conducting the dumbbell shape, so it is a dumbbell shaped test.

So, you can see here this is a pictorial view and this is schematic view, so you can perform the test as per A S T M D 638or D 682 or D 6693 the you can see it is a dumbbell shape, and test specimen are cut from a large sheet. So, this you can see that is 350, so you can see that all dimension is given here as per the A S T M D 638, and then you can conduct this test universal direct, universal testing machine and you can calculate that what will be the tensile strength of the geomembrane.

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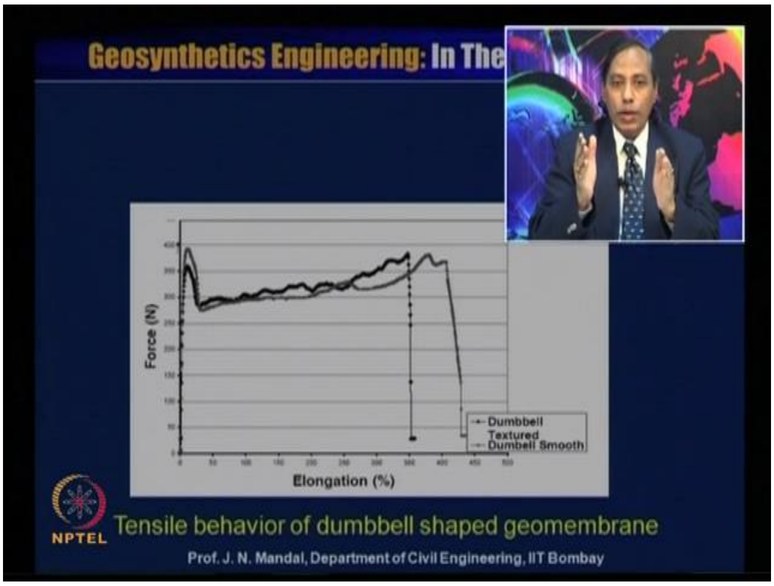

Look at this picture this is tensile behavior of dumbbell shaped geomembrane, this is the force and elongation and this is the dumbbell shaped, structural and also the smooth, you can see that force is increasing elongation is very less. And then it is decreasing, then it is constant and then again it is increasing like this, so it may goes to 400 percentage strain 500 percentage strain and also, it can goes 700, 800, 900, 1100 percentage. So, there are different types of the geomembrane, it may be high density polyethylene it may be P V C polyvinyl chloride, but it is very important what should be their tensile behavior.

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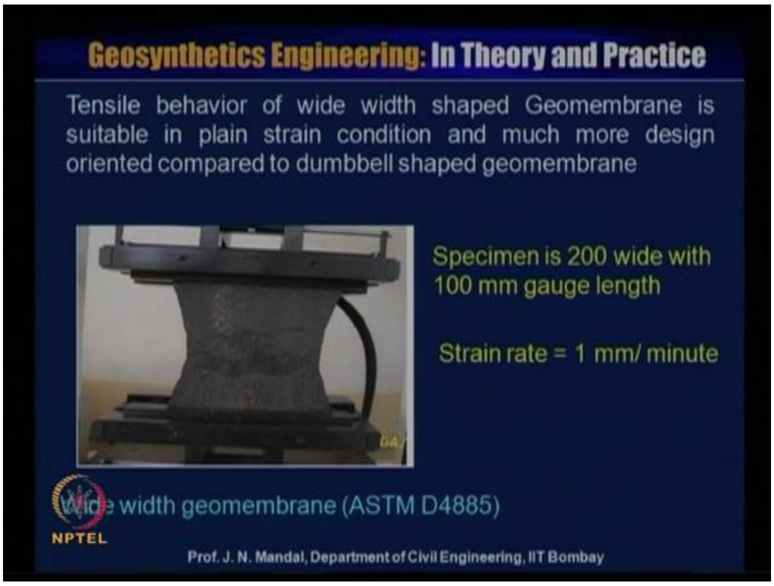

So, I am showing here that if it is a high density polyethylene geomembrane material, and tensile stress has to be conducted whose specimen size is about 200 millimeter wide and 100 millimeter gauge length, and strain rate is 1 millimeter per minute, so this is a wide width geomembrane test. So, tensile behavior of wide width shaped geomembrane is suitable in plain strain condition and much more design oriented compared to the dumbbell shaped geomembrane.

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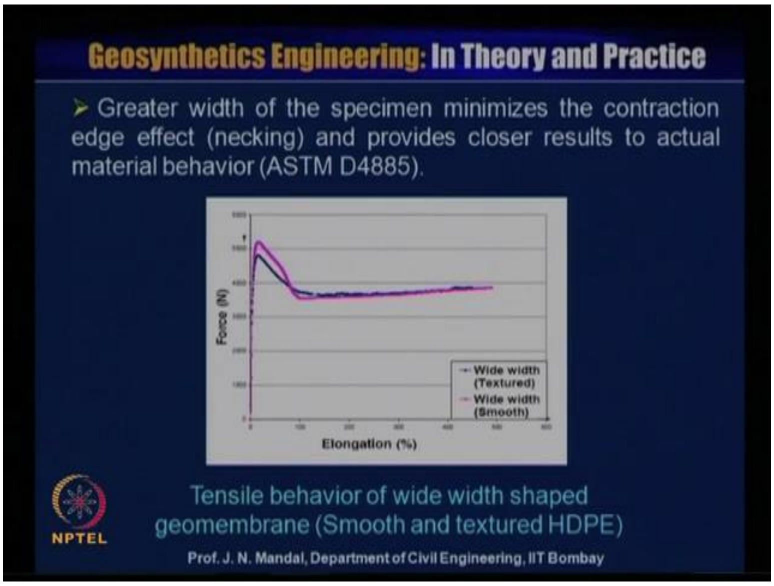

So, you can see here the tensile behavior of wide width shaped geomembrane smooth and textured geomembrane, so greater width of the specimen minimize the contraction edge effect; that means, necking what you can see here and provide closer result to actual material behavior, this is as per A S T M D 4885.

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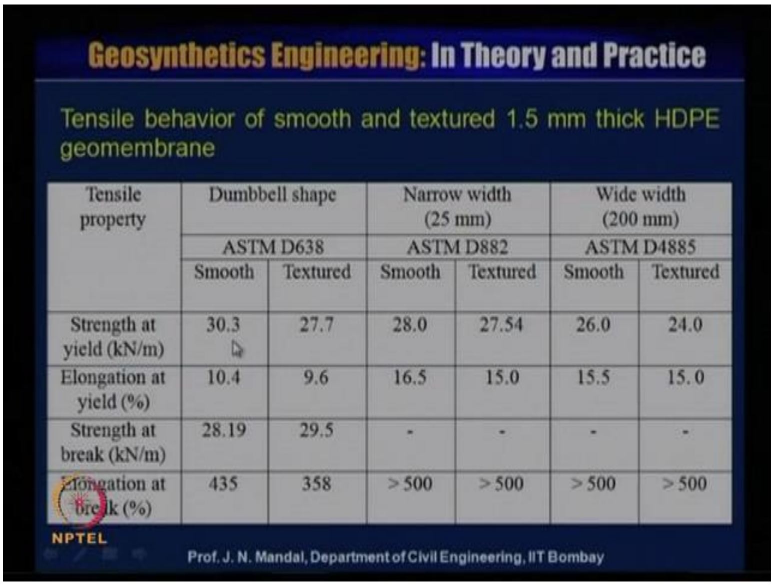

So, you can see that some of the result of the smooth and textural behavior and whose thickness of the H D P E is 1.5 millimeter, this is the strength at yield and this is as per A S T M D 638 and dumbbell shape you can see this is 30.3 kilonewton per meter, textured strength 27.7 kilonewton. If it is a due narrow width 25 millimeter A S T M D 882, then strength at yield 28, this textured case 27.54 wide width 200 millimeter, A S T M D 4885 smooth 26 and textured 24.

And elongation at yield in this case 10.4 percentage this is 9.6 percentage, this is 16.5 percentage this is 15 percentage wide width case this is 15.5 percentage, this is 15.0 percentage. And strength at break as per A S T M D 638 is 28.19 kilonewton per meter and 29.5 kilonewton per meter, but elongation at break is 435 358, it is all greater than 500 percentage. So, you can see that how the strain value is increasing, this has also some beneficial effect for the use of this kind of the geomembrane.

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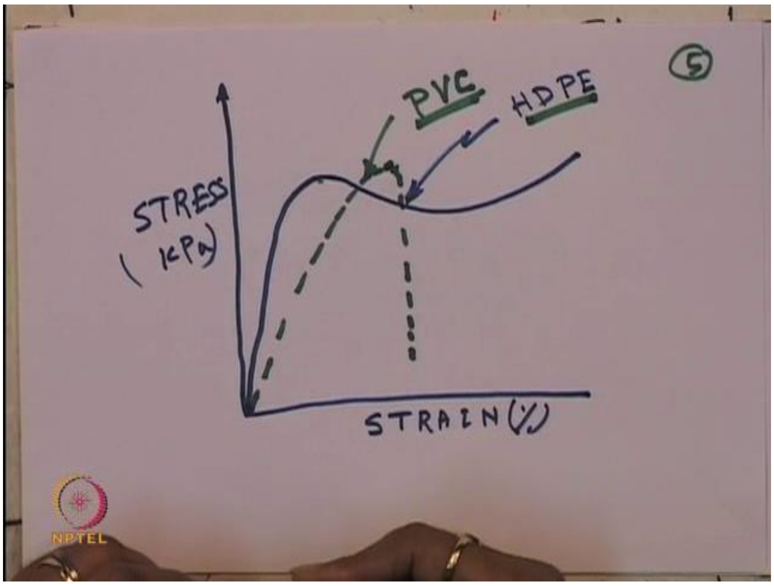

Now, I just wanted to explain about some tensile stress versus the strain responds curve, for H D P E and the P V C for example, this is the stress, this is kilopascal and this is the strain, this is in percentage. So, if it is a high density polyethylene this curve goes like this and then goes like this, then it is increasing like this, so this is the high density polyethylene. Say a kind of ductile behavior, but if we perform the test tensile stress and obtain the tensile stress versus strain respond curve for the P V C.

You can see that this curve goes like this, and then it suddenly drops like this, so this is a kind of material you can say P V C which you call the polyvinyl chloride, so this also brittle behavior; that means, it is sudden failure. So, you can see there are two types of the material one is the H D P E another is the P V C, so you can see that you require the stress and you require the strain for a longer time, gradually is increasing, where you can use the high density polyethylene material for the construction of the landfill problem.

Where, you are dumping all kind of the waste material hereafter here and then you require for elongation for the longer time, so there is no failure you can observe there is most of the cases, no failure in the high strain value. On the other hand, you can see that if you use P V C then it may suddenly break it may give the high stress value, but strain is limited. So, you have to be very careful where you wanted to use the H D P E material, where you wanted to use the P V C material, so depending upon the type of the problem what you require may be the strength not the elongation too much.

So, you can use the P V C, but where you require strength and as well as you require very high strain like landfill construction, then where you can use the H D P E material. Now, this material also when you will join actually one with the other material, you require two kind of the testing and what will be the type of the joint, that is also very important to us.

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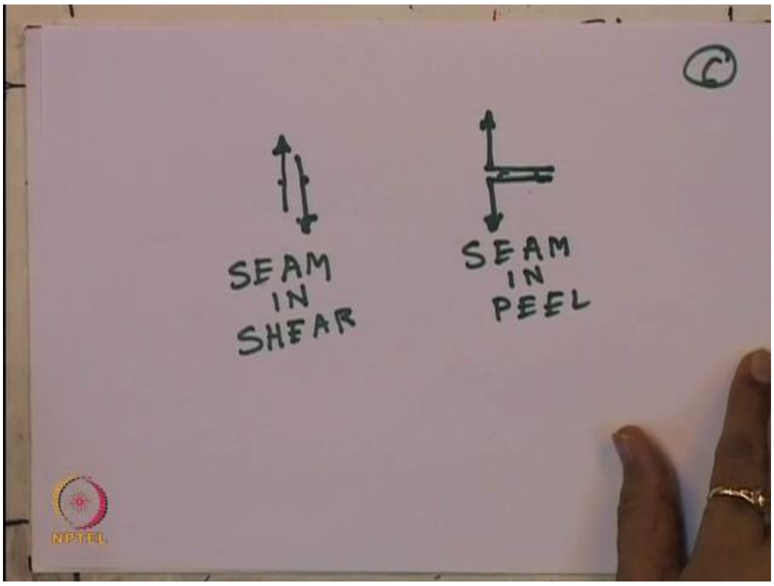

So, I am showing here that what will be the behavior of H D P E sheet and the seam, so this material you can perform the test like this, which you call the seam this is kind of joining seam in shear. You can see this is the material this is geomembrane material, and there is a shear in between the material, you can join and there will be the shear, so you can perform the shear test. So, you will be knowing what will be the seam value in shear and what will be the behavior of H D P E sheet and the seam also, there is another test which you call seam in peel.

So, sometimes you can join like this, so this is the geomembrane material, and then you can seam it seam in peel this is like a peel, so you can see that behavior of H D P C and the seam, so this is seam in peel test. So, you can perform seam in shear, you can perform seam in peel and you can see what should be their behavior, also there are different types of the joining system is there, various method available to fabricate geomembrane seam.

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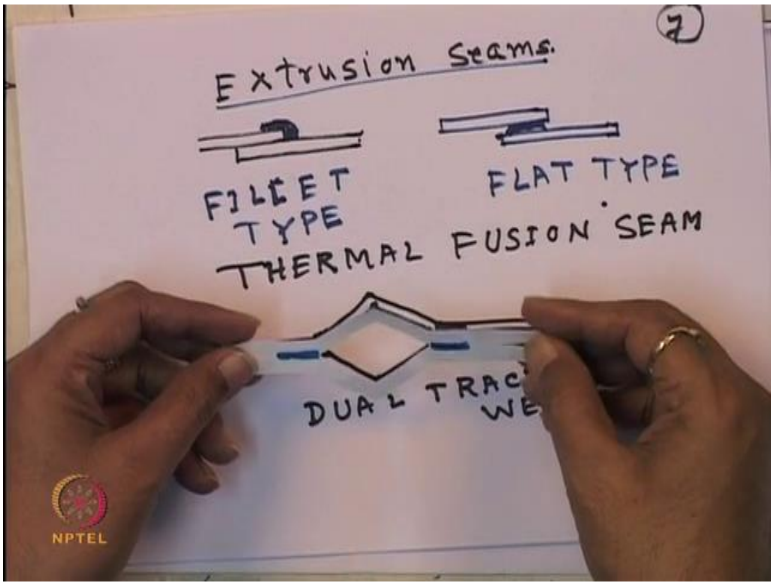

And they are saying that some of the seam one is called the extrusion seam, so if this is the geomembrane and this is the geomembrane and then you have this part here seaming. So, this is called fillet type or you can also make it seam in this type and this is called flat type; that means, this extrusion seam may be the fillet type or the flat type. Also there are other 3 types are there, one is called the chemical fusion, which is the chemical seam another is called the chemical adhesive or which you call adhesion seam and apart from that which is also very important to us that is thermal fusion seam.

So, it is like this, so then you are seaming like this here, and seaming like sorry this will be like this, so it will be seaming like this here and here you can see there is a hole between two geomembrane, so these also called the dual track hot wedge. So, there is a gap, so there will not be development of the pressure and when you want like this, this is the geomembrane and this is another geomembrane and there is a hole, so if any special development can be minimized or can be reduced.

So, this kind of the seaming geomembrane seam is essential for the construction site, so this is very nice or very good bud seaming, so you can see that various type of the seaming, but dual track hot wedge is the best suited for the construction of any project.

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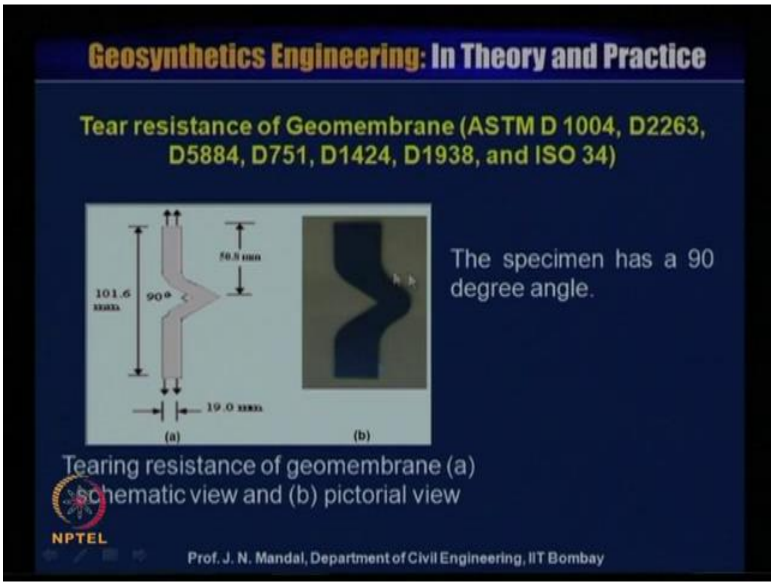

Now, next the tear resistance of geomembrane as per A S T M D 1004 D 2263 D 5884 D 751 D 1424 D 1938, and ISO 34, this specimen has a 90 degree, you can see this pictorial view, this is the geomembrane. And this is the 90 degree, this is 101.6 millimeter, this is 50.8 millimeter and this is width is about 19 millimeter, so you have to put in a universal testing machine and you have to perform the tear resistance of geomembrane.

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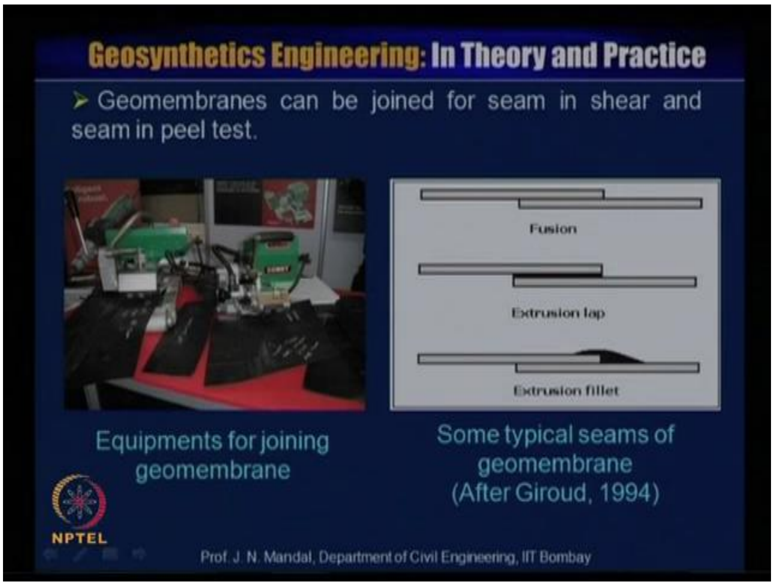

So, this is also important because sometimes it may be tear it up, and here I am just showing that some of the geomembrane, how can be joined for the seam in shear and seam in the fill test this is the machine, which we can join with this. That means, equipment for joining the geomembrane, I have also the explained some of the type of the seam geomembrane, here this is the fusion here is a extrusion lap or this is a extrusion fillet, so this is all given by after giroud 1994.

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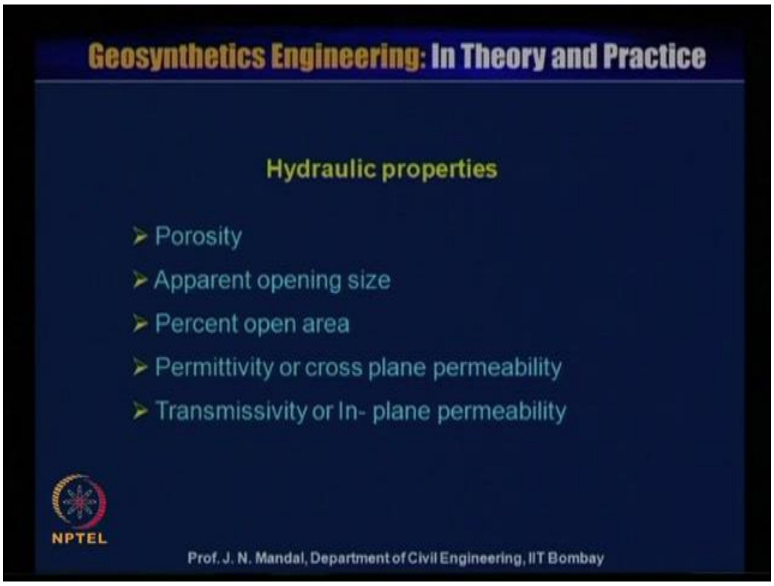

So, hydraulic properties now, we talk about all strain overrated problem for the geotextile geogrid and the geomembrane. So, this is all strain related problem these may be application for reinforced soil wall, it may be application for slope stability problem embankment problem, but also we want to check out the properties of the geosynthetics material in hydraulic related, coastal related problem.

So, hydraulic related properties also are very, very important, this is flow related problem not strain related problem, so we have to perform that what should be the porosity of the geosynthetic material, apparent opening size percent open area and permeability or the cross plane permeability and transmissivity or in plane permeability.

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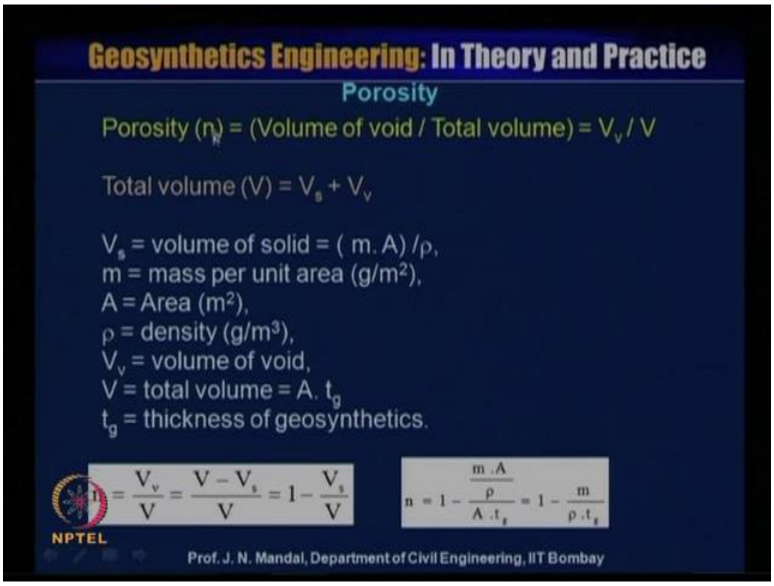

So, how you can calculate the porosity, porosity can be defined as a volume of the void by total volume, so is porosity is against by n is equal to V v divided by V, where total volume V is equal to V s plus V v. V s is equal to volume of the solid and that is m into A by rho m is mass per unit area that is gram per meter square and A is area meter square and rho is the density gram per meter cube, and V v is the volume of void and V is the total volume.

That is A into t g, A is the area and t g is the thickness of the geomembrane. So, you can write n is equal to V v by V; that means, V minus V s by V; that means, 1 minus V s by V, so 1; that means, n is equal to 1 minus this is V s means m into A by rho this divided by your V v is equal to A into t g. So, we can have n is equal to 1 minus m by rho into t g, so if you know m if you know rho and if you know thickness of the geosynthetics material, so you can calculate the porosity this is also very important parameter.

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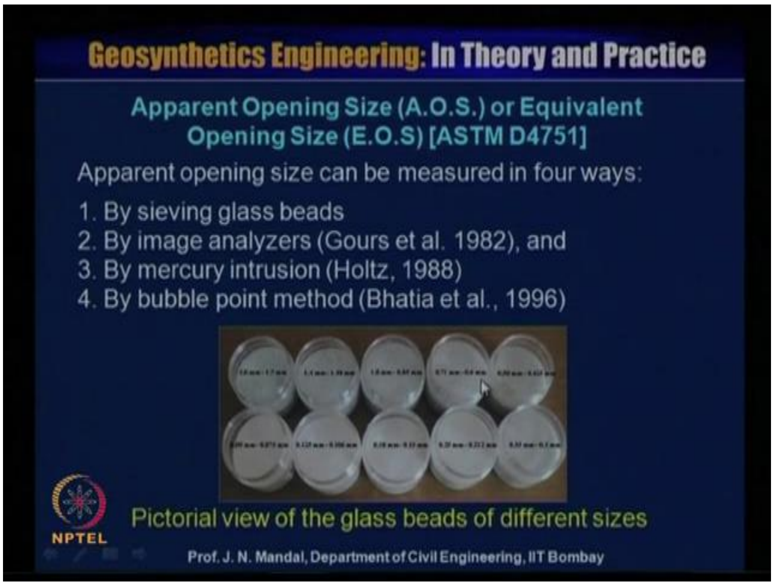

Now, next is apparent opening size or which you call A O S or if equivalent opening size that is called E O S, this is as per A S T M D 4751, this parameter is very, very important for the any erosion control problem, filtration problem, drainage problem. There are various method to measure the apparent opening size, it may be by sieving the glass beads by image analyzer that is Gours et al 1982 and by mercury intrusion that is Holtz 1988 and by bubble point method that is Bhatia et al 1996.

So, we use that glass bead you can see here different types of the glass bead, this 2.8 millimeter 1 millimeter, these you can see different types of the glass bead and we have conducted also the apparent opening size of the some of the material.

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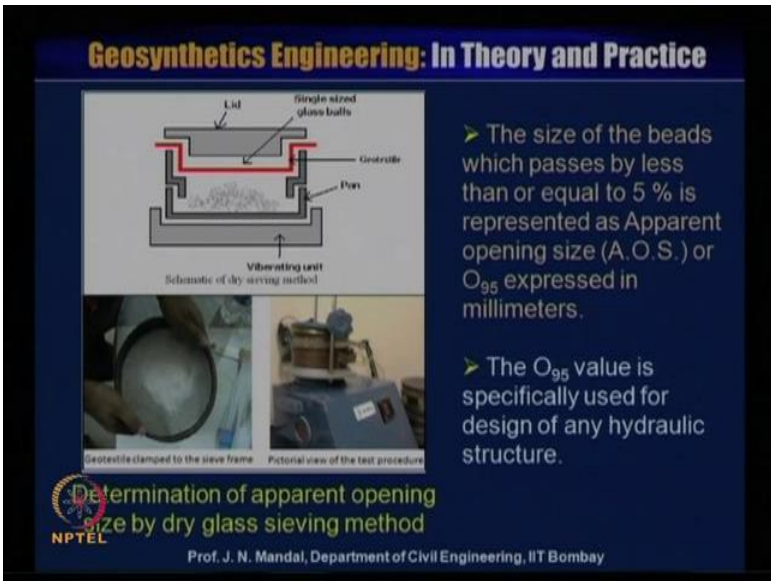

So, this is the geotextile, this inside geotextile clam to the seam frame, and this is the pictorial view of the test procedure and you can see this is the this is the schematic of dry sieving method, this is the vibration unit and this is the pan. And this is the red color is the geotextile material, and the this is the glass bead is passing this is on the top of this is the lid and the size of the beads which passes by less than or equal to 5 percent is represented as apparent opening size of the geotextile or O 95.

This you remember O 95, because there are some the use also that O 90, but A S T M specification given O 95 and this O 95 is expressed as millimeter, so O 95 value is specifically used for the design of any hydraulic structure. So, this is very important that how you have to calculate the apparent opening size of the geotextile.

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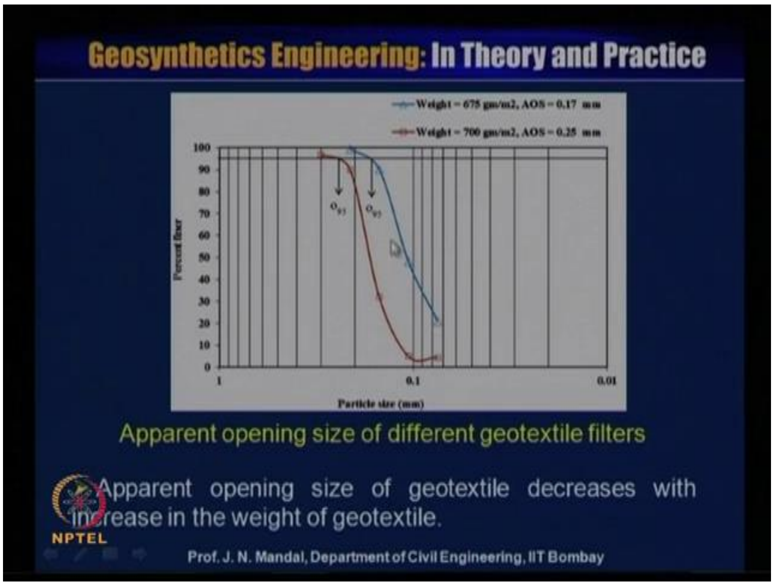

We have performed some of the test, this is the this test show the apparent opening size of different geotextile material, and it has a percentage finder y axis, and the particle size in millimeter on the x axis. So, here this showing that weight 700 gram per meter square and you can see this is the O 95, so you can calculate the what will be the particle size in millimeter. So, for this weight is about 700 gram per meter square and apparent opening size is 0.25 millimeter and this is another sample whose weight is about 675 gram per meter square and apparent opening size O 95 you can calculate as 0.17 millimeter.

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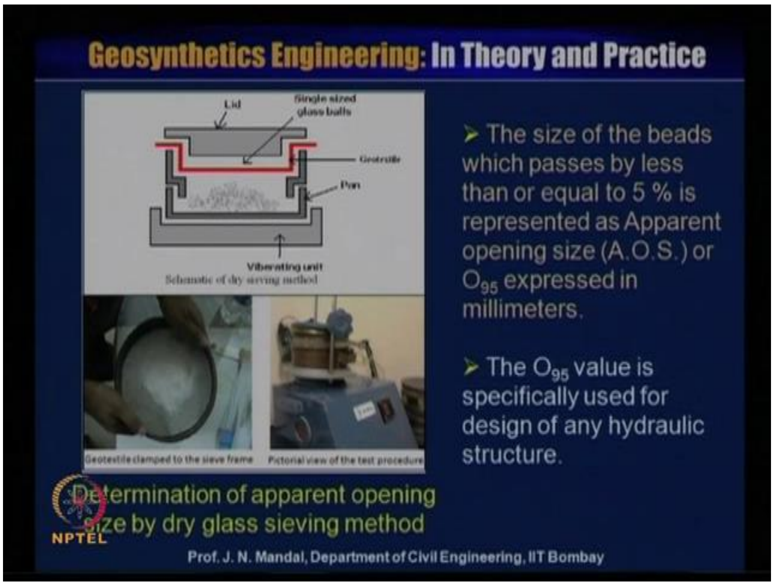

You can see O 95 that what I said that only that 5 percent is represented, so size of the bead which passes by less than or equal to 5 percent you represent it as O 95, so O 95 you can calculate.

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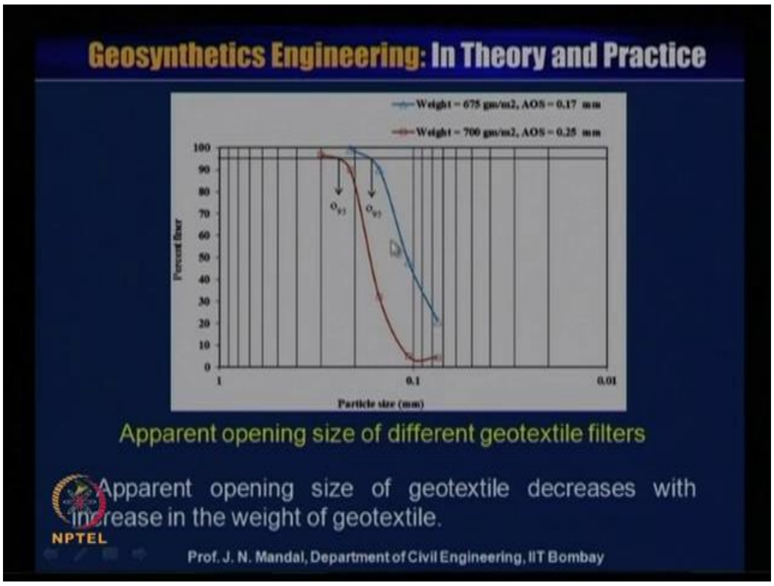

So, apparent opening size of the geotextile here are decreases with the increase of the geotextile weight of the geotextile material, so this is very important parameter.

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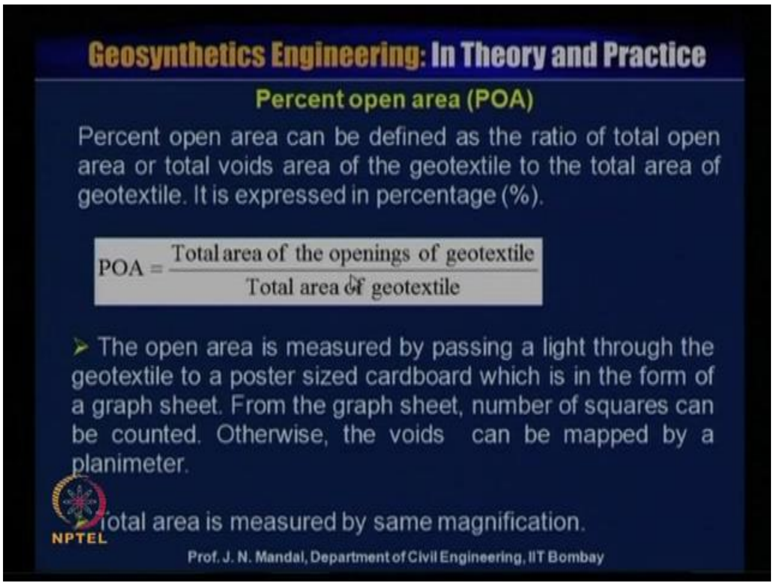

Now, percent open area, percent open area can be defined as the ratio of total open area to total void area of the geotextile to the total area of the geotextile, it is expressed in percentage. So, percent area can be expressed as P O A, that is the total ratio of total area of opening of geotextile to total area of geotextile material, now the open area is measured passing a light through the geotextile to a poster sized cardboard which is in the form of graph sheet. From the graph sheet number of square can be counted otherwise the void can be mapped by a planimeter, so total area is measured by the same magnification.

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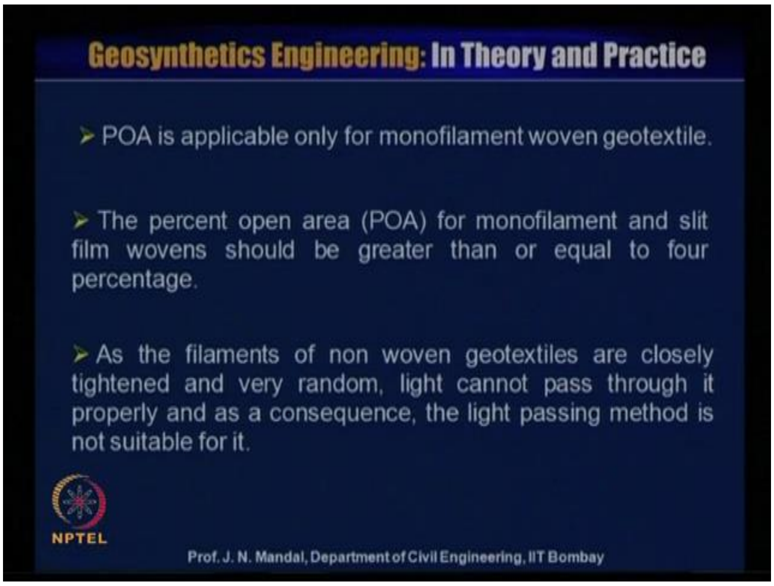

Now, P O A is applicable only for monofilament woven geotextile, the percent open area P O A for monofilament and slit film woven should be greater than or equal to 4 percentage. As, the filament of non woven geotextile are closely tightened and very random light cannot pass through it properly, and as a consequences the light passing method is not suitable for it, so it is preferable to perform the test for the woven geotextile rather than the non woven geotextile material.

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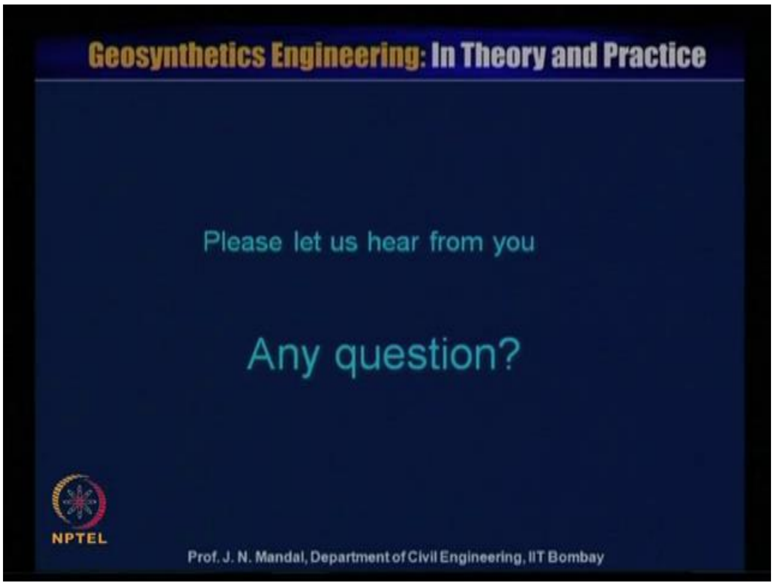

I ended up this lecture here, please let us here from you any question.

Thank you for listening.