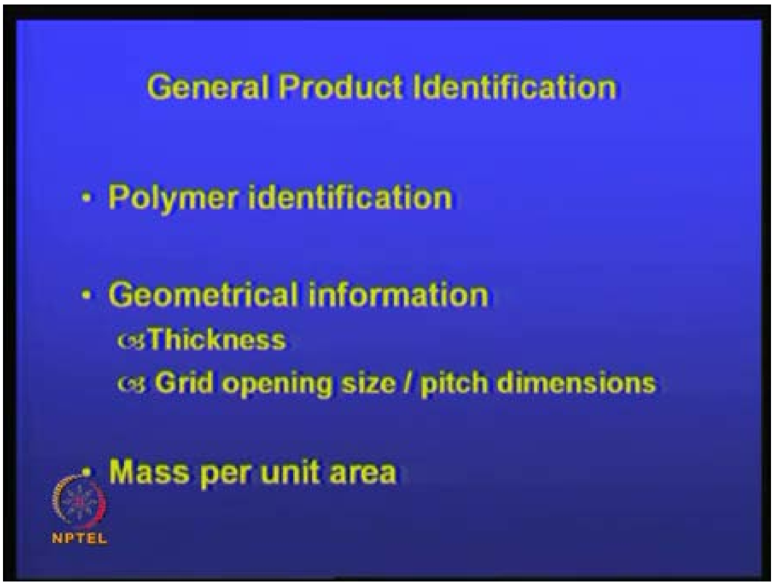
Ground Improvement
Prof. G. L. Sivakumar Babu
Department of Civil Engineering
Indian Institute of Science, Bangalore

Lecture No. # 26
Material Properties

Today would be talking about material properties of Geosynthetics as, I just mentioned in the previous class, the geosynthetics have been very useful in ground improvement projects.

(Refer Slide Time :00:26)

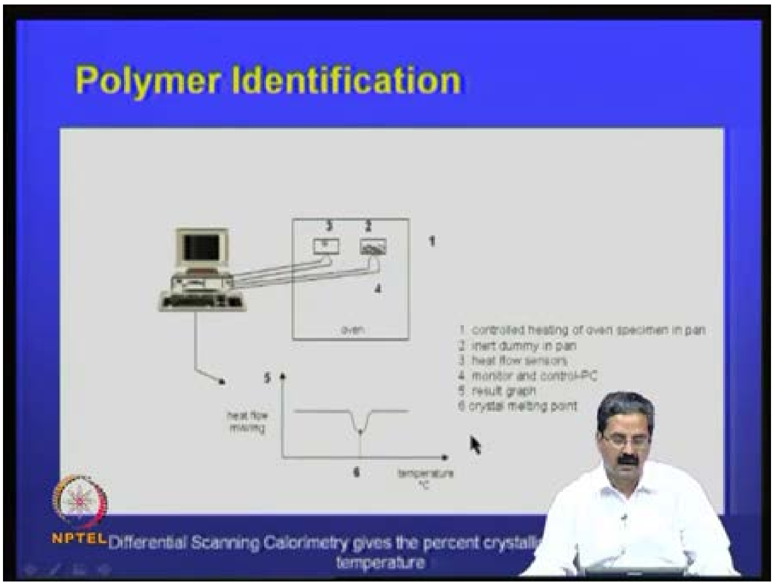


Hence, it is essential for us to understand, what type of materials they are composed off and what are their applications, of course, we have seen that, they are very useful in many applications.

And how do you identify them, how do you characterize them, how do you what are the properties required different applications we should see. So, in this lecture, we would be seeing, how the polymer materials that exist in all these geo synthetic materials is determined, how do you evaluate the mechanical properties and hydraulic properties and all that.

Actually, we should first of all identify what is that material. In fact, if you have a geocomposite or a geogrid or a geotextile, we should be able to identify what type of polymer you have, because as I just mentioned they are all polymeric materials, chain of carbon and hydrogen atoms. You should be able to know about geometrical information, what is the thickness, grid opening size; and what is its mass per unit area, like, what is the weight of that material, that that is a general product information.

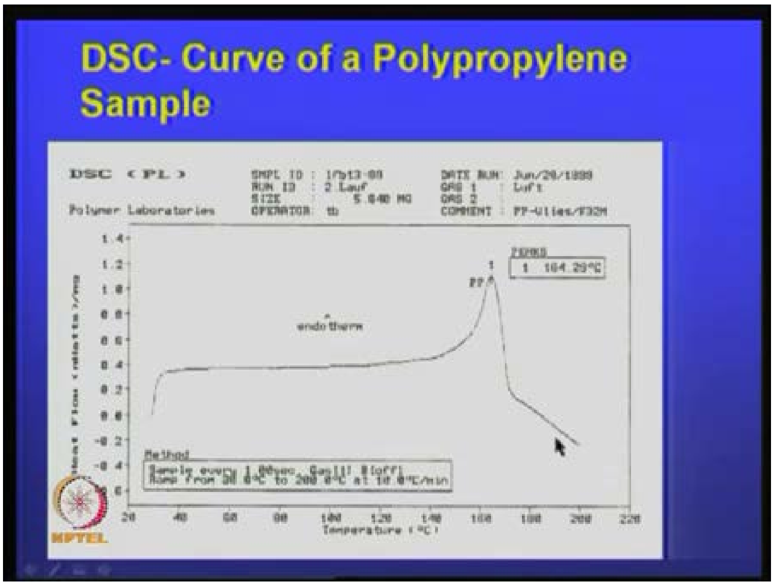
(Refer Slide Time :01:31)



In fact, if you want to identify the polymers, there is a test what is called differential scanning calorimetry; when which you have a sample here, then you heat, you know, you have a sort of a control heating, and then once you heat rise the temperature, there is a what is called heat flow is monitored as a function of the temperature.

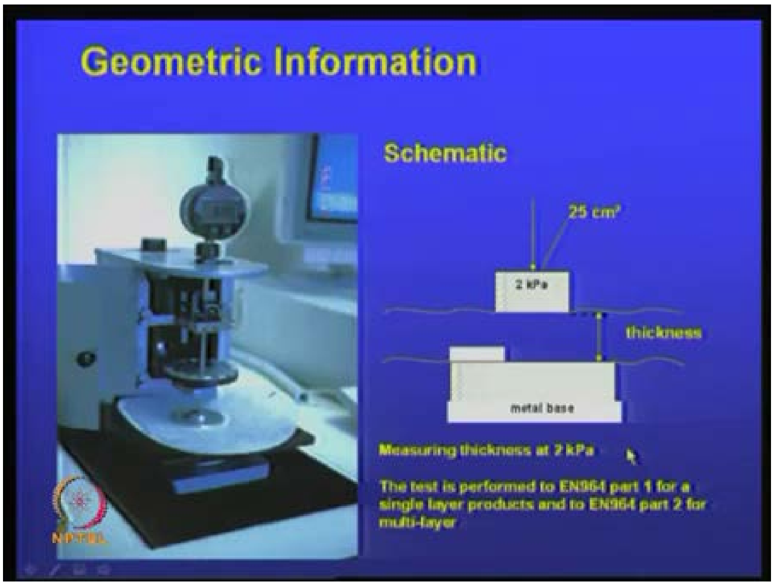
And there are certain products, they depending on the type of polymer, they give certain signatures like, say for example, here you have a crystal melting point, which is number 6 here, like, these are all the this a graph and all that you will have a result like this.

(Refer Slide Time :02:24)



Then, the crystal melting point is somewhere here; it is a function of the type of polymer you have; and so, that can be used as a basis to identify the type of polymer. So, for example, here, you have the polypropylene product, you have a about 164 degrees, 0.29 degree centigrade, you have this type of result you get and people can use some of these materials for whatever is the application that we are interested in.

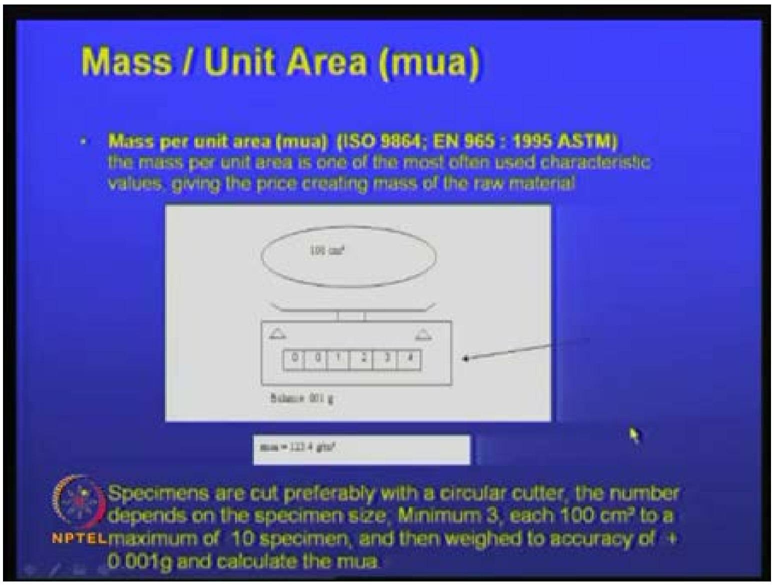
(Refer Slide Time :02:45)



The geometric application, actually the thickness is quite important, because we have seen varieties of materials, they have different thicknesses. And as I just mentioned, we have to standardize at one pressure, at 2 k P a, we measure the thickness; actually this is a thickness of the sample, this is a weight and area of cross section is there.

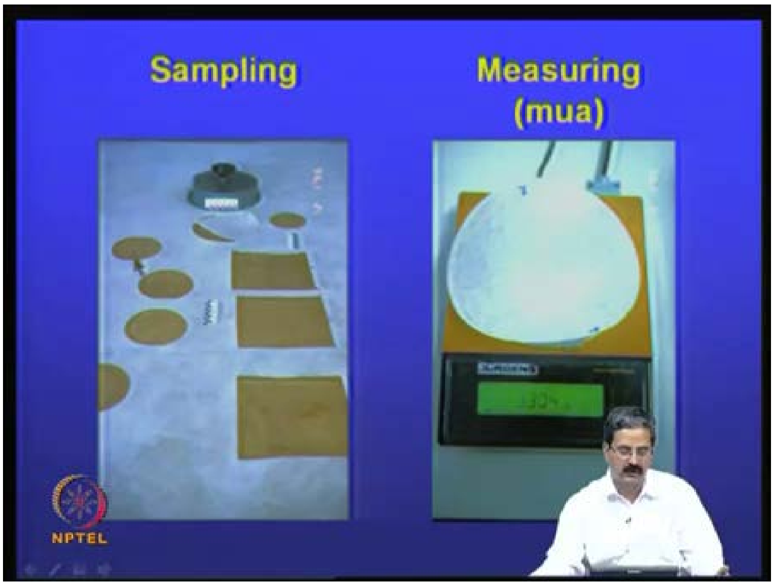
So, we try to calculate it is thickness, because this is required in many of the properties like, you know, permeability, you know, like, if you want to look at filtration and drainage criteria, thickness is a very important parameter.

(Refer Slide Time :03:18)



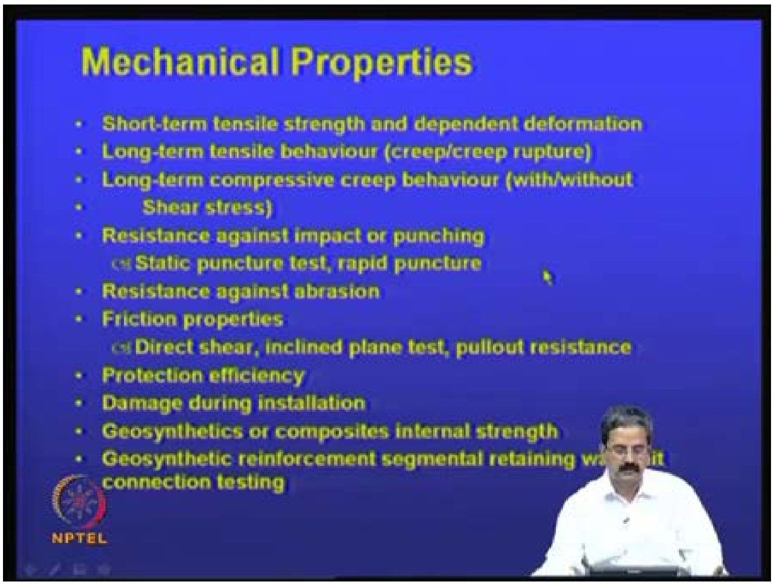
We also need to know it is a mass per unit area, which is called we know mua and it is one of the very important applications here again. And you try to take a small circular piece of geosynthetic material and then weight; so, you take its weight. And In fact, as I just mentioned, the quality of a paper and the quality of silk is also measured in terms mass per unit area.

(Refer Slide Time :03:46)



This is how we do it; we take some samples and then weigh them, and then you have property it should be nicely cut, because there is a special cutter there, that should be used.

(Refer Slide Time :03:55)



Mechanical properties is what we need in most of the applications. So, we are looking at short term tensile strength and corresponding deformation; long term tensile behavior, like, it can be in terms of the long term means; the time dependency like, you know, you just wait for different periods of time and then find out, if what is a change in tensile strength.

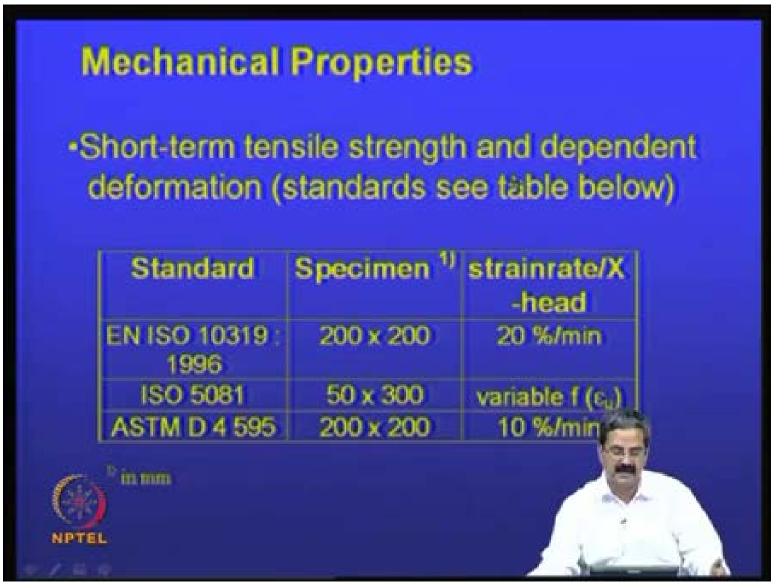
Then, long term compressive creep with and without shear stress. In fact, we do this in soil mechanics like, we apply load and then at the same stress level, we allow it to settle for longer time; we call it creep behaviour.

Then, we also have what is called resistance against impact or punching; this is another test. This is all required in many of the like, as I just mentioned survivability require survivability requirements are there for geosynthetics, if they have to really perform well, they have go through some of these tests, like, so for durability, you have a resistance against abrasion.

And friction properties, like, we know that, friction between the soil and reinforcement is very important for effective working of the reinforced soil structures. So, to measure the frictional properties, we have direct shear, inclined plane test, pullout resistance test.

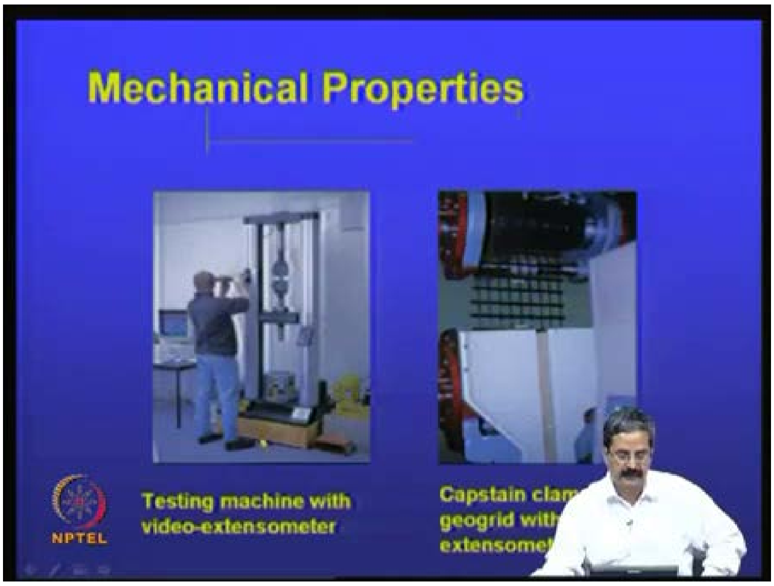
We have protection efficiency test also, which will tell you about, if you have you know, if you want to protect a particular product, and so, you need to have, you need to have some sort of question for it. So, does is a product does have that protection efficiency? Is it not? That sort you would like to see here. Damage during installation is another one. And there are many properties that we need even several example, if you are trying to use a compose segmental block, type of structure in the case of a reinforced earth walls, I just showed you in the previous figures, previous classes, you need to even do a test for that.

(Refer Slide Time :05:54)



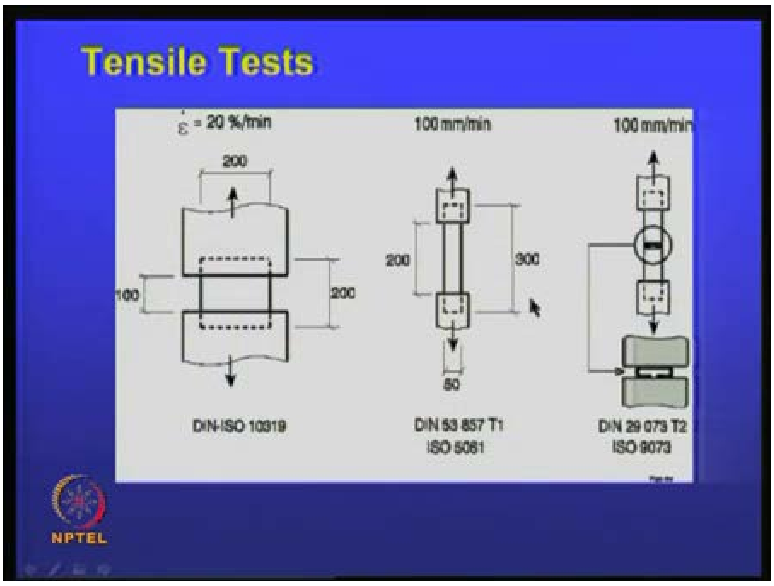
In fact, short term tensile strength means immediate tensile strength and you have certain standards for it, and this a specimen size is at 200 mm by 200 mm, this is a size and then the strain is given also. These are all actually, you have European standards, you have I S O standards, you have ASTM standards, all these three things are very important, because if you are in Europe, you may try to follow it; ISO is a general standard, ASTM if you are in US, they you know go by ASTM standards.

(Refer Slide Time :06:25)



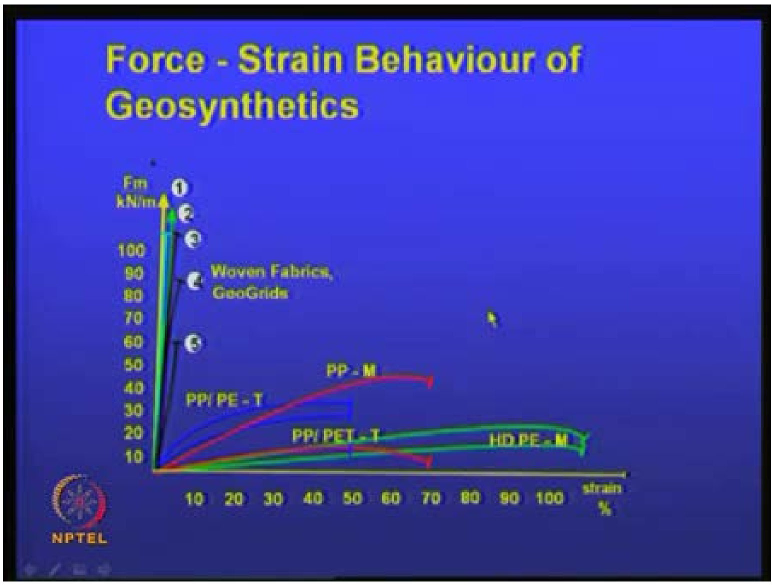
Mechanical properties you can see that, see this is a material that is being tested; here is a geogrid or a geotextile here. So, testing machine with video extensometer like, you know, they see that deformation in the on the strain using sophisticated equipment, such as video extensometer. Here, they are trying to use laser extensometer; you have a geogrid here, you can see that, it is being pulled up and they are trying to measure that strain.

(Refer Slide Time :06:56)



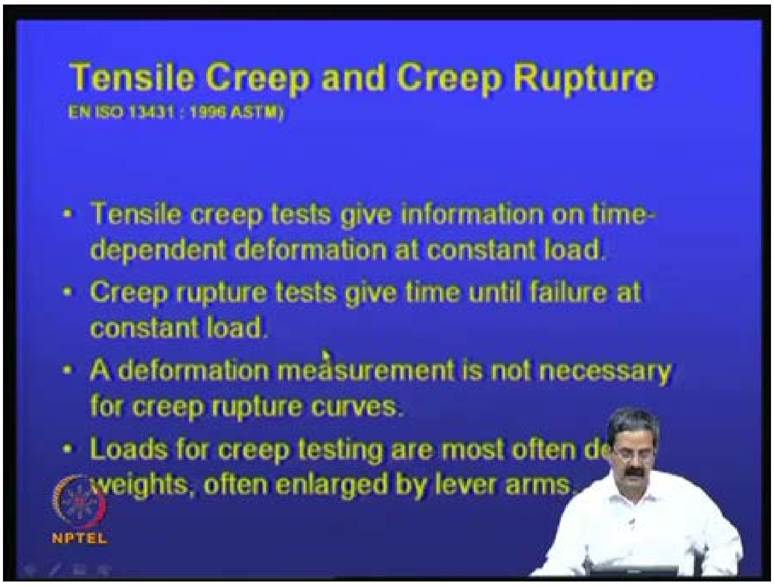
So, these are all different standards as I just mentioned. And then, there is a rate of application of load is also mentioned; 100 mm per minute, and so, this is like, say, in this case, it is a 20 percent per minute, like this they have some. So, these are sample size, here as I just mentioned, these are all sample sizes.

(Refer Slide Time :07:16)



If you want to look at the response, say for example, strain versus kilo Newton per meter length is what you observe. So, you can have varieties of stress-strain curves, depending on the material stiffness, like, you can have you know varieties of, this is what is going to be very importantm if you are trying to design for reinforcement functions.

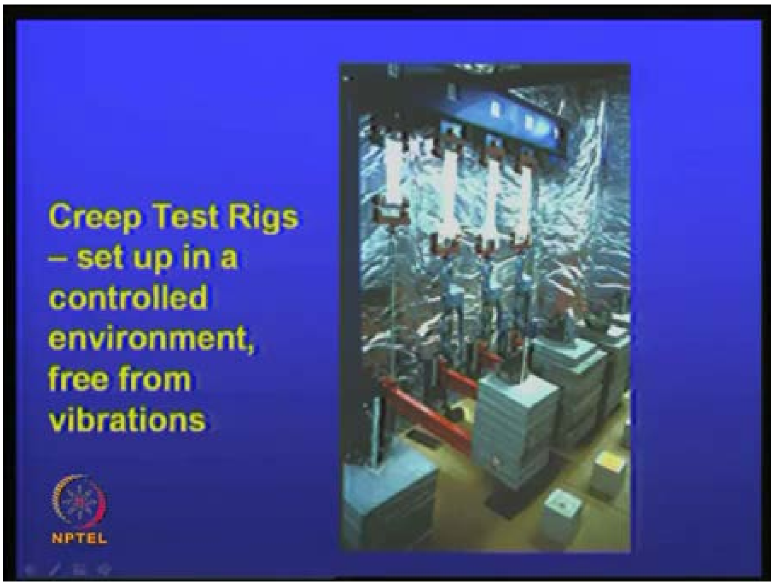
(Refer Slide Time :07:39)



And the other important properties called tensile creep, like, you are doing a tensile testing, but then you allow apply the same load, but still there is a creep, you know, like, if there is a load that is applied. So, the tensile creep is an important parameter; it gives information on the time dependent deformation at constant load.

And then, sometimes there is a it also fails; so, it is called rupture. So, sometimes you see, you keep on pulling the same material or the same load is applied it, because of the molecular arrangement as I just mentioned, even with because of the time, there is a deformation that occurs, even if the load is same. So, that needs to be calculated.

(Refer Slide Time :08:26)

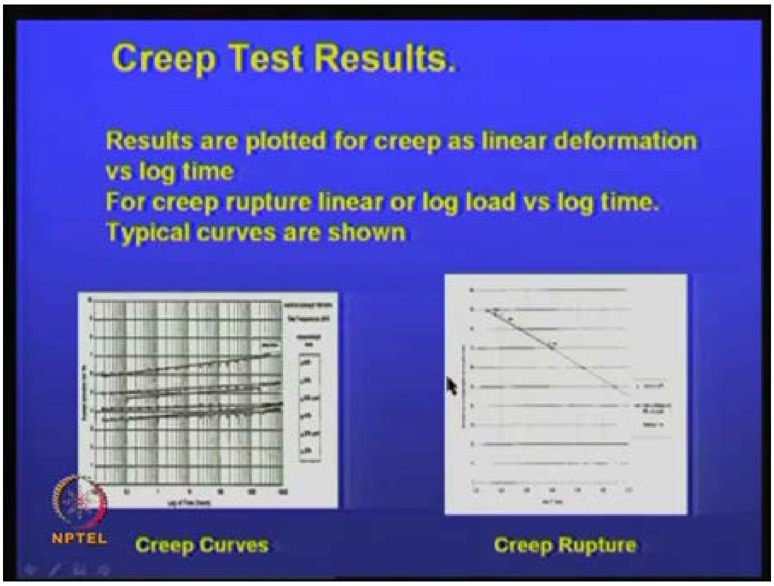


So, we use constant loads; we will just see that, this is like this, say, you have a geotextile piece here, like, one, two, three, four pieces, you have constant load applied or you can even a lever arm application is can be there.

(Refer Slide Time :08:37)

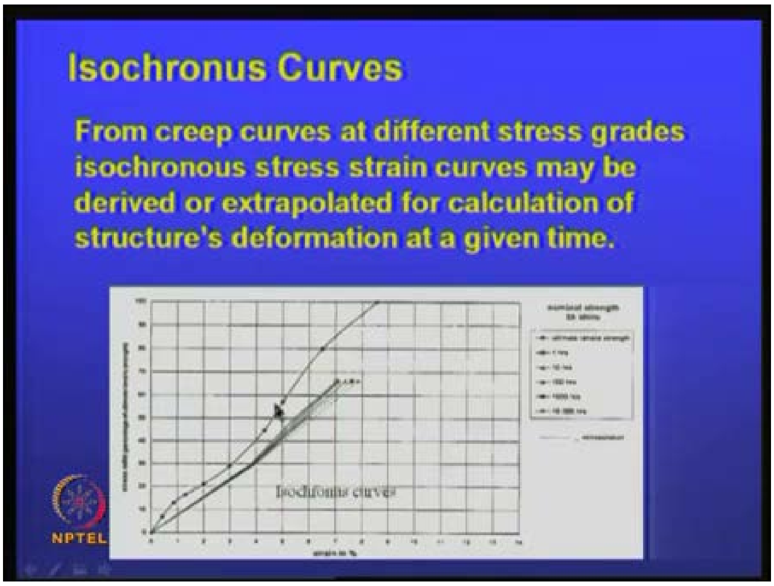
And multiple creep rupture rigs in a temperature controlled chamber, in fact, in a chamber where you have multiple materials tests are being done, and all that this is one.

(Refer Slide Time :08:49)



The way that results can also be plotted is like this, you know, one can say, for example, you can plot some of this different stain level, different loads actually, different loads like, say for example, 50 k p a, 100 k p a and different loads can be applied, and you can monitor this creep curves versus time; say for example, 50 k p a, one load; keep on observing its deformation, you will get a stain like this, may be, 100 k p a like this, 1000 k p a like this. So, at some higher stresses, what happens? It the curve may show like this, it will kink also, which means that there is a rupture there and it cannot take higher loads, that is what it means.

(Refer Slide Time :09:38)



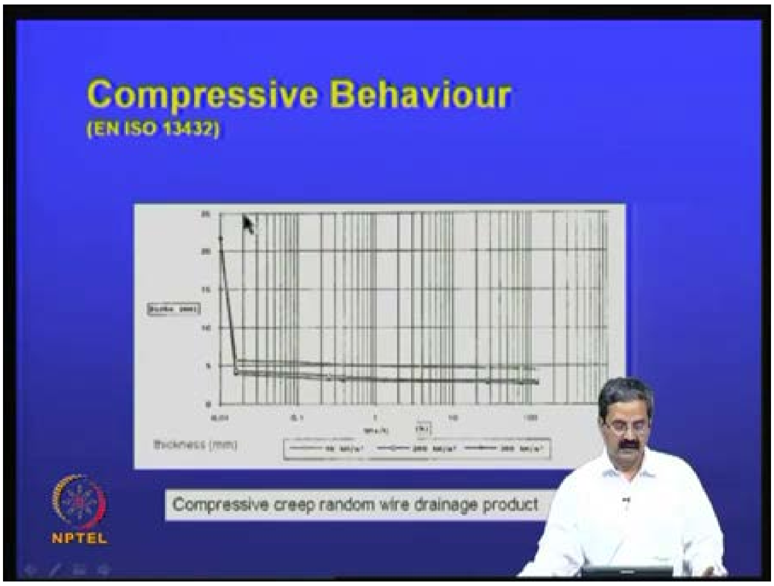
And so, creep rupture is one possibility; this is the way that we construct creep load curves. And from this, we construct what we called isochronous curves, which means that, at the same time, we would like to see what is its effect of, say for example, here the tensile strength of that geogrid is or geotextile material is 35 kilonewton per meter.

And this is this stress strain curve, immediately after the ultimate tensile strength immediately after the product is delivered to you or something immediate is a rapid test. Then after one hour, this is one test - one stress strain curve; and then, like one hour, you know, ten hours, hundred hours, thousand hours, ten thousands hours.

So, actually code recommends, say for example, we want to calculate… see the thing is that, why is this isochronous curves are required is that, you would like to estimate the tensile strength of the material after say in its life time, say for example, 30 years you would to construct or 40 years you would like to construct. So, if we want to correct, you need to have, how much of strength reduction is there from immediate condition to long term condition. So, we measure this, we get this information from this curve.

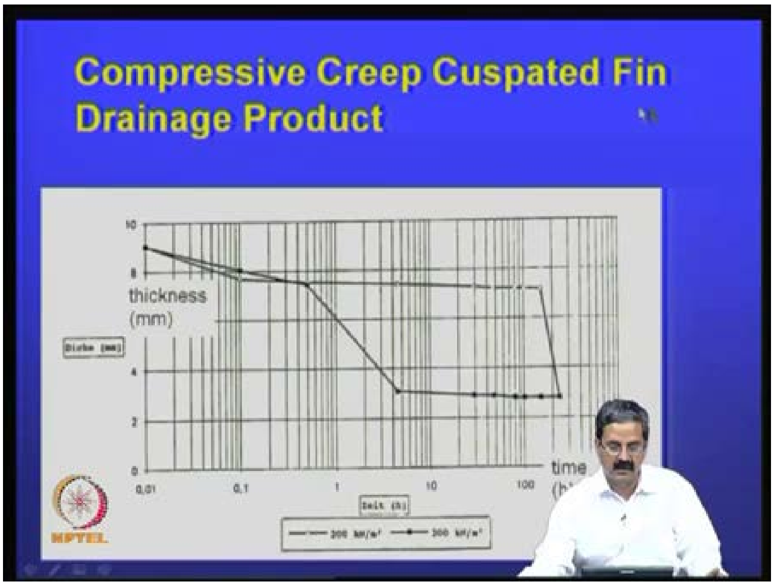
So, different materials have different properties like this, and you can use this as a basis for correcting your tensile strength in the design, that we will see say; for example, if the tensile strength could be 35 kilonewton per meter, then if you want to see that it works for about, say for example, 50 years, you may have to use a factor of - creep factor of - 1.3 or 1.5 or whatever. So, it depends on this type of testing.

(Refer Slide Time :11:24)

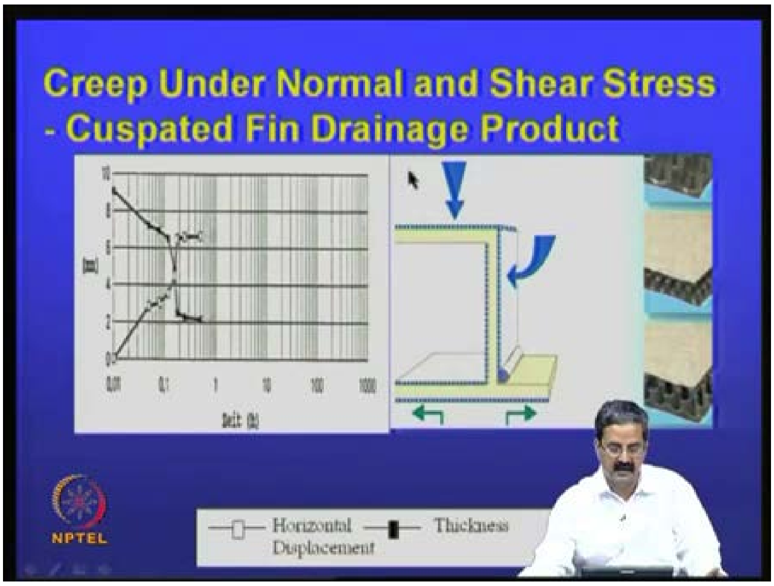


Then, it is another thing is a compressive behavior, like, as I just mentioned many of these materials are also compressible, right. So, one can see that compressibility behavior as well in under different confining pressures. Particularly, this is very important in the case of a drainage products, because as I said water flow is very important, and if the compressibility is going to be more, the drainage is less.

(Refer Slide Time :11:47)



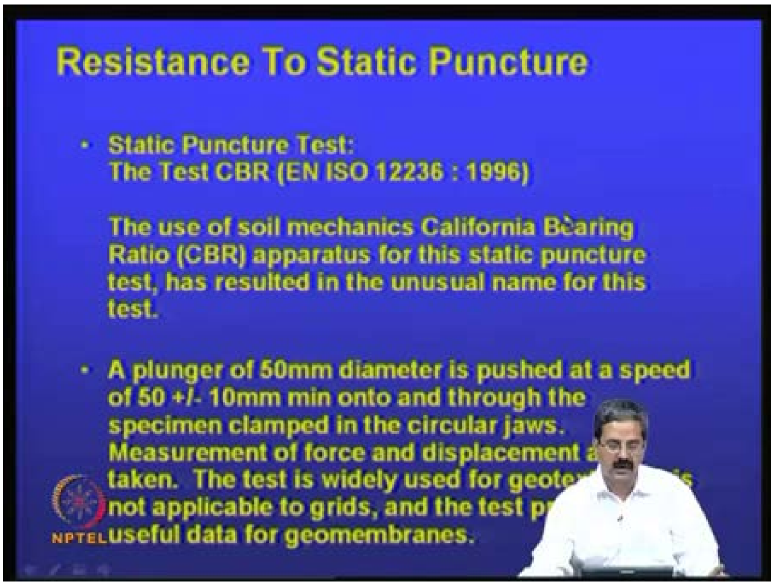
(Refer Slide Time :11:55)



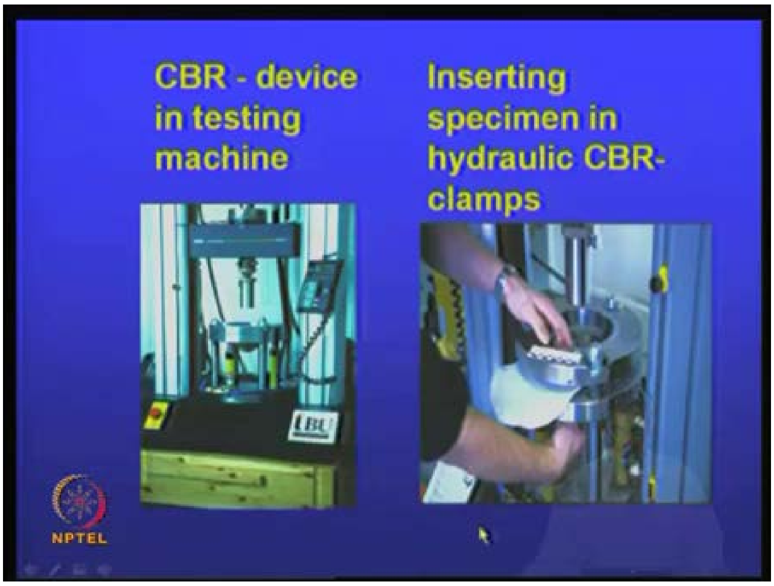
Compressive creep in a another product, which is called cuspated fin drainage product like, it is like this you know. It is another interesting project that we have, which we use it for many of the drainage applications, say for example, in the case of retaining wall, it looks like this; you can see that, it has some sort of projections and all that; it is a fines, they are all called fines.

You know there are. So, instead of putting a backfill next to the retaining wall, you have a material like this, which can be useful has a drainage material. And then, it is going to be very permanent and where and then thickness is also much less; and it is going to be much cheaper compared to a sand or a any of the gravel material, right. So, these are the some test that one should do.

(Refer Slide Time :12:33)

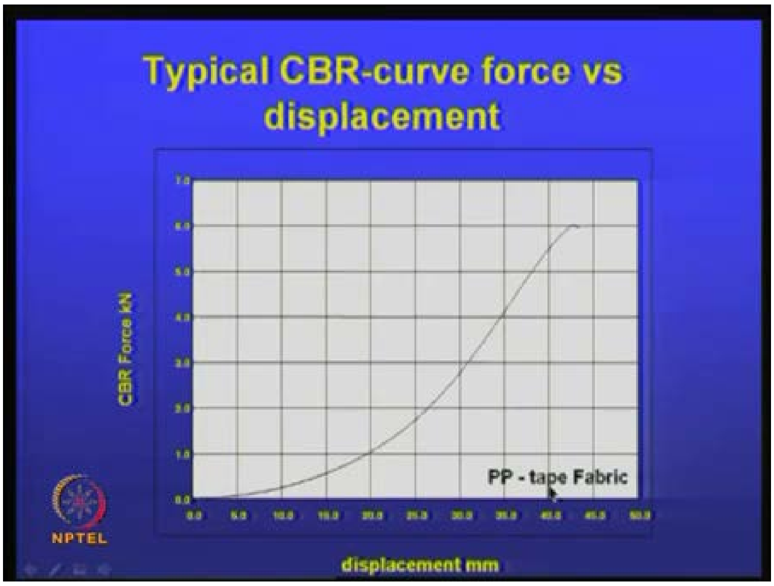


(Refer Slide Time :12:46)

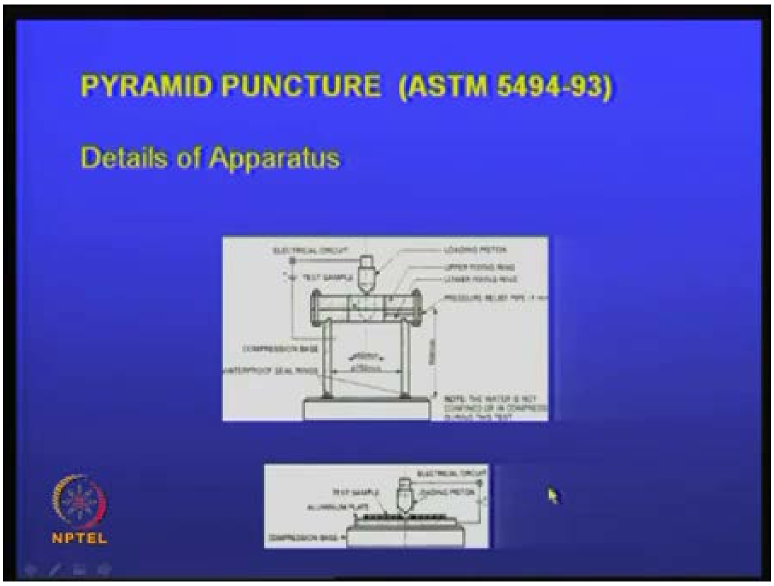


And resistance to static puncture: actually, this is actually a modification of the CBR test, because what we do is that, here we try to use this test for, you know, things like this; you know CBR test, we try to make a puncture here, means, you know, we try to measure the load here; essentially we try to say, similar to the C B R test, we measure the load versus deformation; here also we get the same thing.

(Refer Slide Time :13:00)



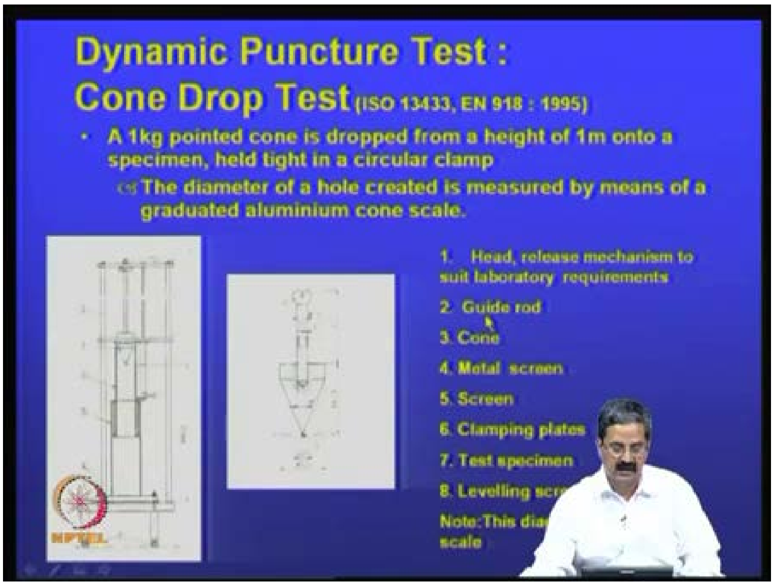
(Refer Slide Time :13:09)



See, how much of load it can take is, like you know, we will get this, like, this is on a polypropylene tape fabric. There is also say people have, you know, the thing is there is a, you know, a textile industry, actually people in the textile industry, they are also used to tensile testing and all that.

They have used some of their testing methods to even characterized geosynthetic materials; that is, that is a reason we have what is called a pyramid puncture test also, in which you have a material like this; and this is as per the ASTM standard and here is that material and this is like this.

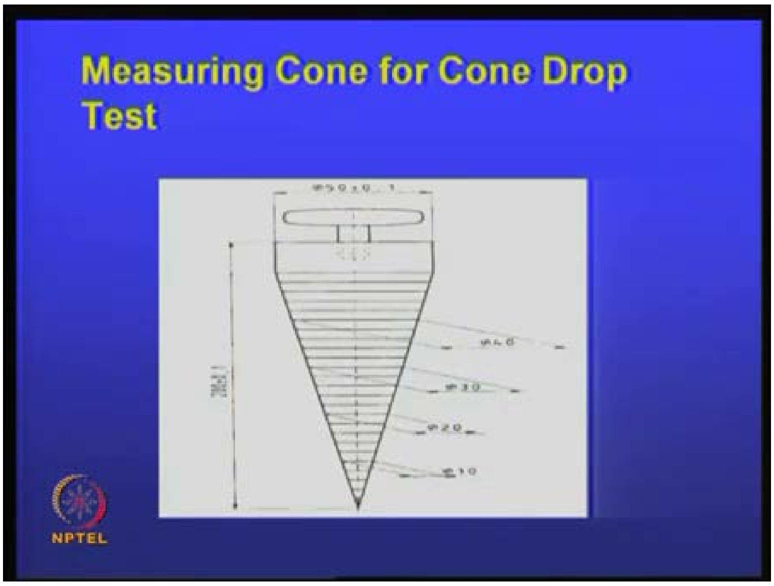
(Refer Slide Time :13:42)



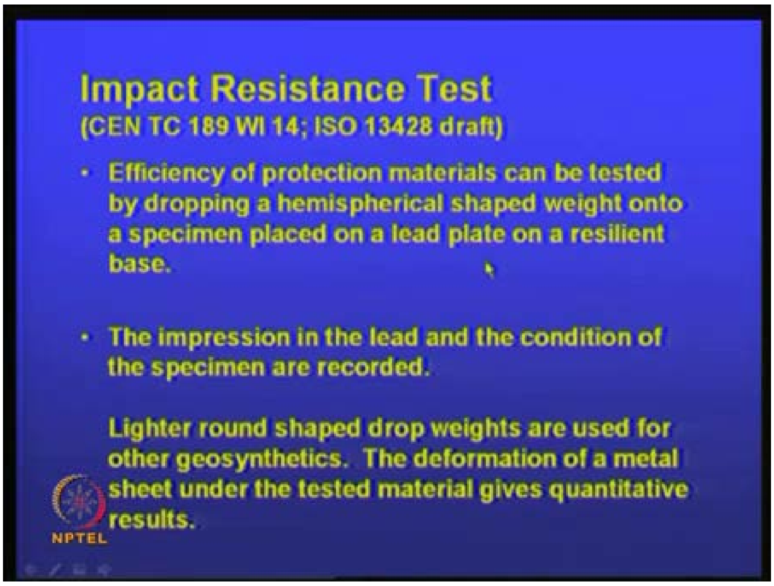
You have a dynamic puncture test in which a cone is dropped from a height, about a one kg pointed is dropped from the height of about a 1 meter onto a specimen, held tightly in a circular clamp. The diameter of the hole created is measured by means of a graduated aluminum cone scale.

So, what is a diameter it has all that? We there are some measurements, like you know, how much of puncture it can give. In fact, many some of this stress are index test, but they are you know very useful in deciding about the product. So, this is that cone dropped test.

(Refer Slide Time :14:11)



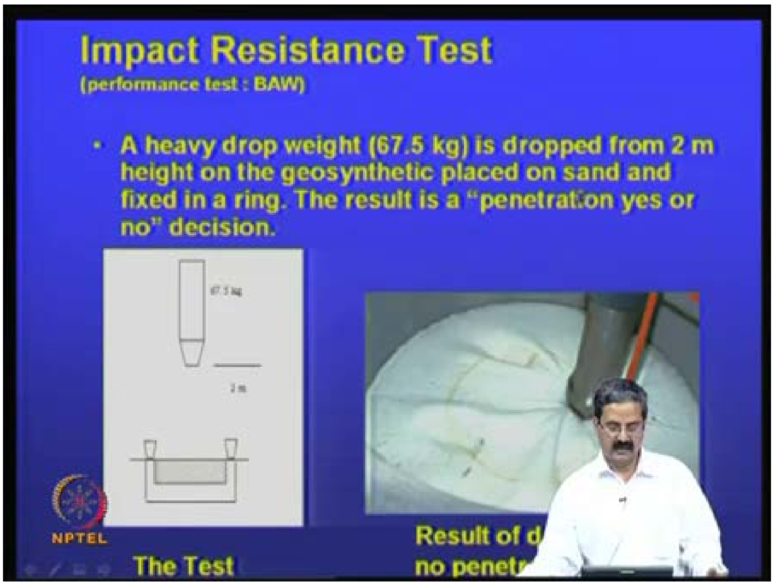
(Refer Slide Time :14:15)



There is another test called impact resistance test, in which again here a hemi spherical shaped weight is dropped onto the lead plate on a resilient base. The impression in the lead and the condition of the specimen are recorded. Lighter round shaped drop weights are used for other geosynthetics. The deformation of a metal sheet under tested material gives quantitative results. This is what is called impact resistance test; this test is in many of the standards here, ISO standards as well.

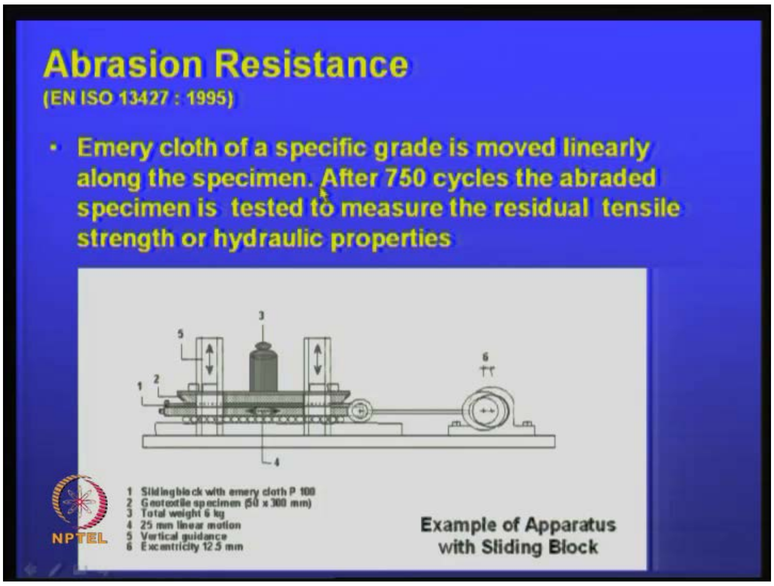
(Refer Slide Time :14:46)

(Refer Slide Time :14:53)



This is how it is done, like, as I just mentioned a small, drop weight, lead platen, specimen under ring. And this is what it does, you know, you can see that , this is impact resistance test, this is standard test actually. This is how it is done layout and this how you know after that this another same type. And the result is, penetration yes or no, that is what it is shows; and if there is no penetration, it is suppose to be good like that.

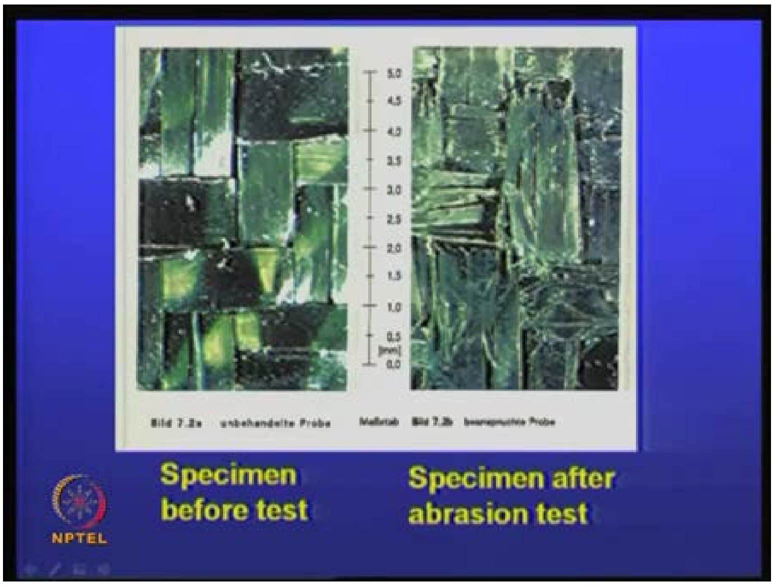
(Refer Slide Time :15:29)



There is another test called abrasion resistance test, like emery cloth of the specific grade is moved linearly along the specimen. After 750 cycles, the abraded specimen is tested to measure the residual tensile strength or hydraulic properties.

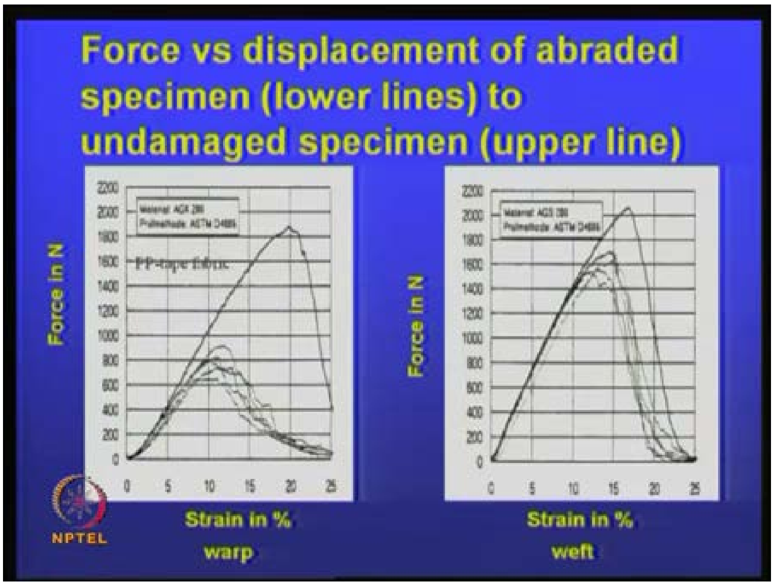
Actually what happens is that, abrasion is one important property, where the it can influence the both tensile strength and hydraulic properties. So, we try to have a geosynthetic material here, and then subject it to an 750 cycles of rubbing actually, you know, using emery cloth or specific grade.

(Refer Slide Time :16:03)



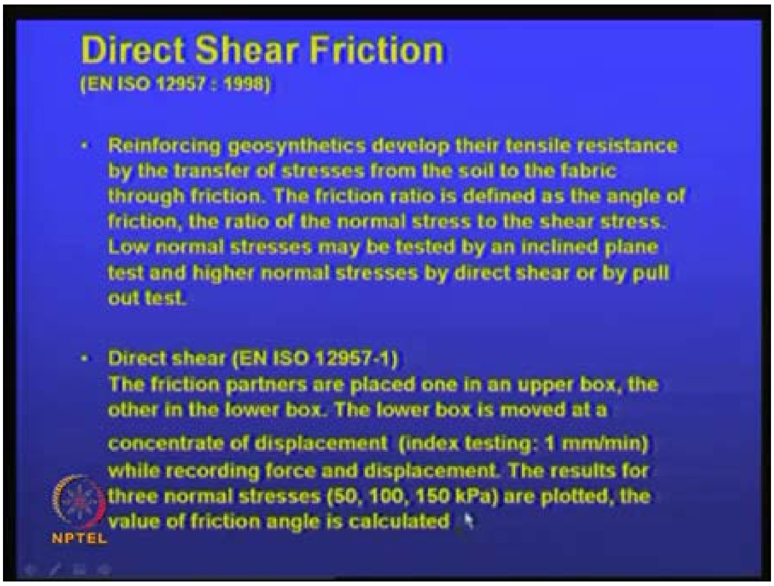
So, you can see that, before test, like a geogrid was like this or a geotextile; after the number of repetitions; it is like this. These also an indication of the quality of the material.

(Refer Slide Time :16:15)



So, they also get the force versus displacement of an abraded specimen to undamaged the specimen, like you know, this is undamaged one; this is all damaged ones. So, they try to measure, so depending on the type of material, you can find out it is thing also like what is it is a tensile strength; depending on the there are two directions, you know, in a geotextile, you have a warp direction, weft direction, and that is that the standard textile engineering terminology.

(Refer Slide Time :16:48)

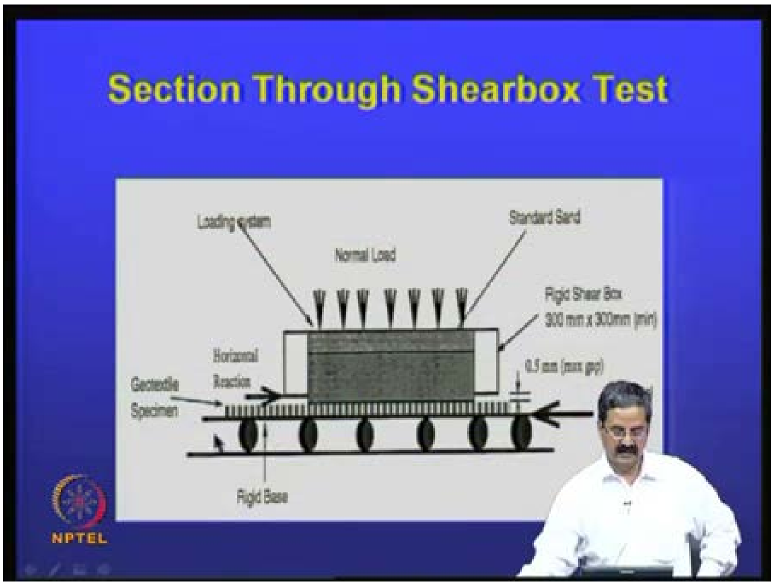


Then, there is another one what is called direct shear friction. Here, the direct shear friction is something that is very important, because as I just mentioned, it is the reinforcement reinforced soil is essentially because, you know, there is a friction between the soil and reinforcement, and that friction is converted as a tensile force.

So, you have to really measure the friction. If you want to see if a geogrid or a geotextile material is going to be good, you have to find out the friction like, similar to our friction angle of the soil we try to calculate the friction angle of the geosynthetic also, like we called it angle of interfacial shear resistance, like similar to tan delta, which we use in soil mechanics. It is similar to we normally have a tan phi, but if there is a pile foundation, we say that, we use a factor called tan delta, which is nothing but two thirds of tan phi.

So, similar to that, we have a friction parameter here, which is a combination of ratio of normal stresses to shear stress; we get from this, actually it is a ratio of shear stresses to normal stresses. So, the direct shear test is done, that is one thing.

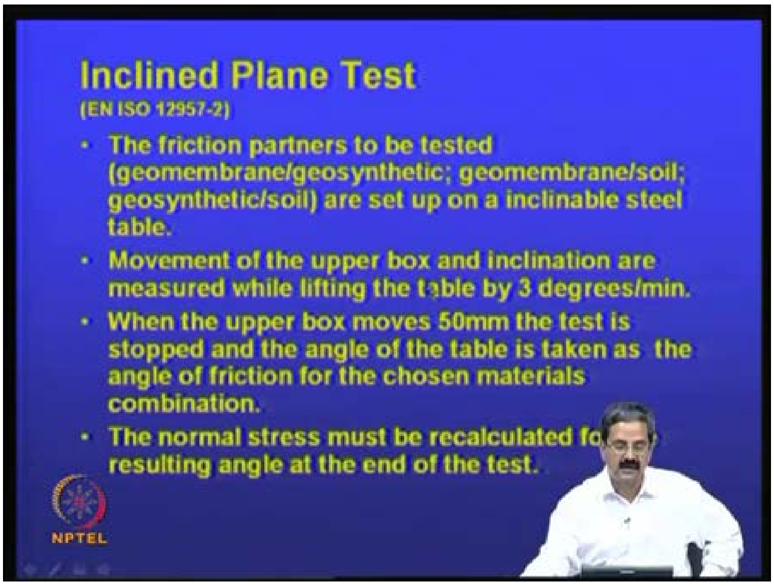
(Refer Slide Time :18:06)



And this is like this, you know, direct shear test we are familiar; and what we do is, that here it is one thing very important is that, see the our direct shear test whatever we have needs a bit of modification, because you must be able to in direct shear, we do a normally a sample here, you need to do a for a big sample, say not less than one foot by one foot or something like that, which represents the actual field condition.

So, you must be able to take a geosynthetic material here; you can see that, there is a horizontal reaction applied, there is also normal force applied. In fact, one should be able to see, here the direct shear box size you can see 300 mm by 300 mm; the size is quite big. And so, this is a shear force is applied like this and then normal stress are there. So, that is one type which we are familiar.

(Refer Slide Time :18:54)



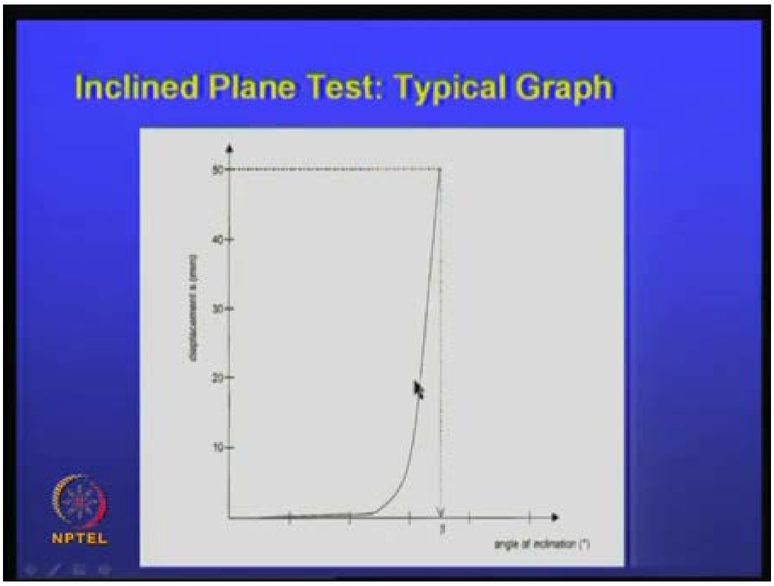
There is also another test which is called inclined plane test. Here, the friction parameters like geomembrane to geosynthetic material, there are so many friction between two materials; one is geomembrane geosynthetic in a landfill, geomembrane soil - geosynthetic soil.

So, whatever is the combination, you have to put on an inclined, say for example, one can have a table like this, any table. And so, the movement of the upper box and then inclination are measured by lifting the table by three degrees, say for example, you have this a particular box is kept and if the if the if the angle is slightly changed, so you try to see the movement of the upper box and its inclination both will be measured. When the upper box moves 50 mm, the test is stopped and the angle of the table is taken as a angle of friction for the chosen materials combination.

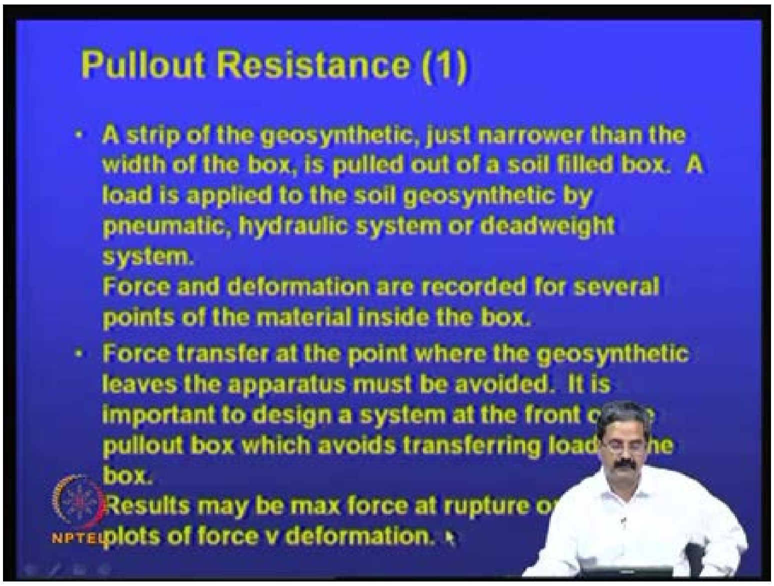
So, whenever the box moves about 50 mm, then we stop the test, and the angle at which you know the table is inclined, it taken as the angle of friction for the materials; so, that is very important. In fact, there are some landfill failures that occurred, what happens? As I just mentioned, though these materials are very nice, so we I told that geosynthetic membrane is very smooth. And if you really do not measures it is properties properly, then there is a the some failures occurred in it, we have it in literature. So, one should measure some of these properties properly.

So, here what they do is that, you can get this material here, the friction angle here, and the normal stress must be recalculated for the resulting angle at the end of the test; this also very important.

(Refer Slide Time :20:44)



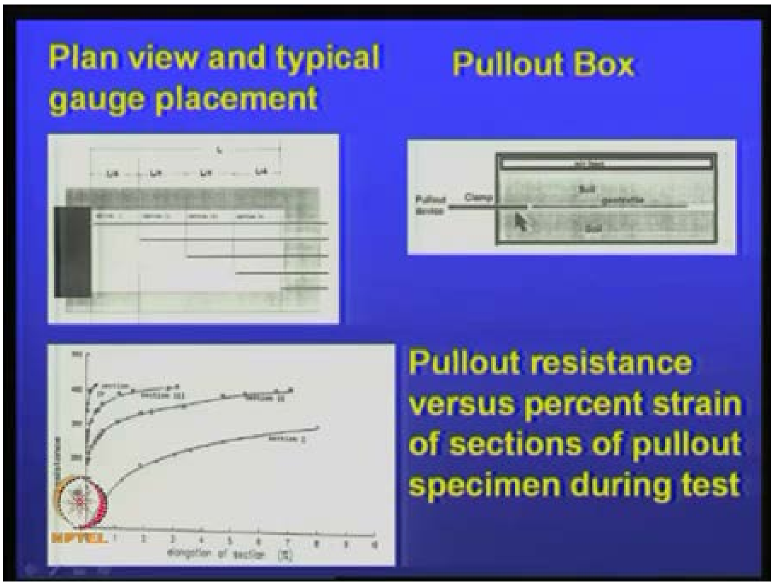
(Refer Slide Time :20:56)



So, you can see that a typical result corresponding to a 50 mm, right, is taken as the angle of you know friction angle. This is another test which we have to do is called pullout test. Actually, as I just mentioned the concept of reinforced soil, you have a friction in the active zone; and it is a some, it has to be hold in a position here back side, that is called pullout resistance.

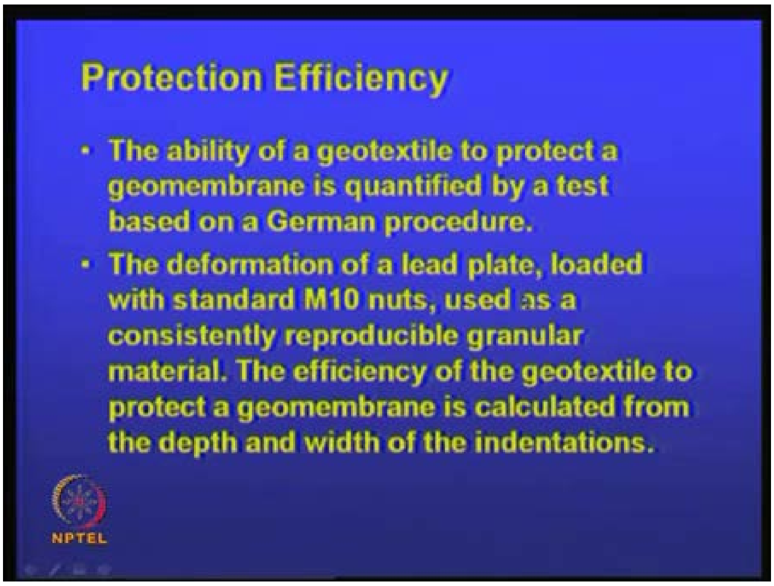
So, that pullout resistance is very important for effective functioning of the geosynthetic material. And the way that we do here is that, we calculate pullout versus deformation. You pull out a geosynthetic material or a even I will show you in the case of a soil nail, just may be in next lecture, you try to pull out the material and calculate its resistance. So, that is what we do. So, we try to plot the results in terms of the how much of mm it has come out, what is the load it has taken. So, force versus deformation are recorded like this, elongation of this thing.

(Refer Slide Time :21:54)



So, different . So, you will have this, like you know, what you are doing is that, this is a soil, this is a soil, you try to pull out this material - pullout device - is there; you have, you know, some it is a big sample actually, you cannot do a samples of small size here. It should be to want to really to be realistic with what you call the field - observed field – conditions, we should do big samples. So, this is one type that we are doing.

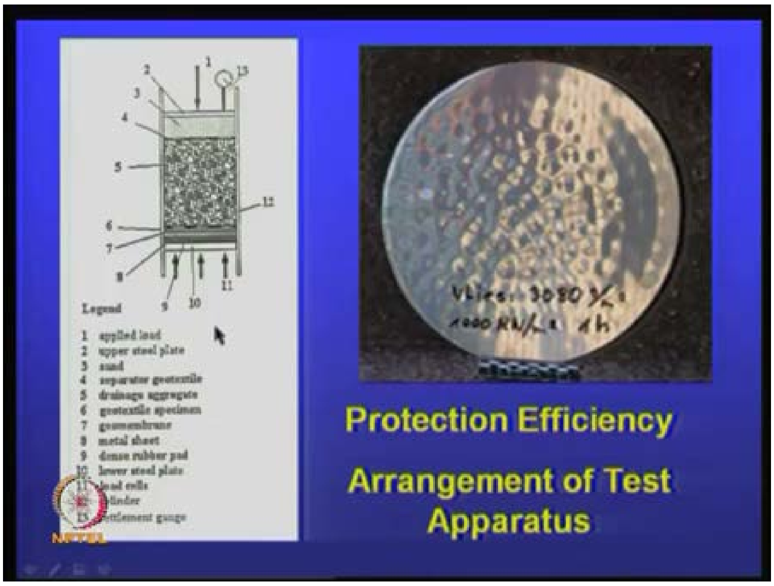
(Refer Slide Time :22:30)



Then, there is another test what is called protection efficiency. Protection efficiency is the ability of the geotextile to protect a geomembrane; it is quantified by test based on German procedure. In fact, I was working in this laboratory in Germany, where they developed this method. Actually, as I just said, landfills are there, landfills are you know, you have to have a geomembrane; actually geomembrane is a very important thing, that the permeability is very low there because of the geomembrane.

And if geomembrane gets punctured, then it is a problem; so, people have a what is called a protection layer. So, you put a protection layer, and this is nothing but it is a simple experiment that they do, like, I will show you that, see this is the type of test that developed actually.

(Refer Slide Time :23:13)

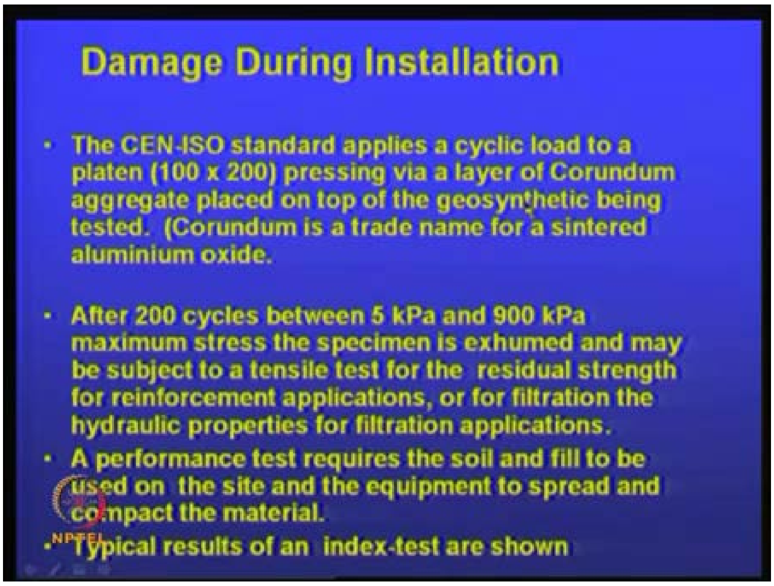


So, seven is the geomembrane, then you have a geotextile; this is actually the aggregate. Actually, see, we normally use in the landfill, aggregate as a… even in a payment also, we are using aggregate as a drainage medium, so but then the drainage medium should not puncture the geomembrane.

So, we try to put a geotextiles a protection layer and we try to find out it is indentations here like this. And then, we try to calculate how much of indentations or depressions are created; there is what you call, if there are not much depressions, then the protection efficiency is very good; if there is a lot of depressions, then, yeah I mean, the material is not that good.

So, we need to really, people do some sort of testing. In fact, it is the institute where I was working it is called (( )), it is in Germany; they develop this test, because they had lot of… no normally, you know, they do innovations actually, you know. So, this is a standard worldwide standard now.

(Refer Slide Time :24:23)

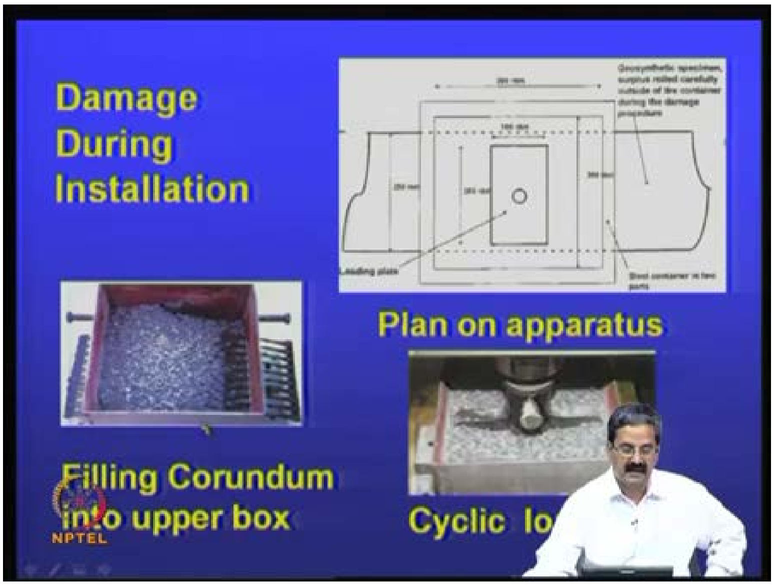


And there is another test what is called, you know, if you want to understand what is a damage that can occur during installation. Again, this is an European standard, in which you have a cyclic loads applied 200 cycles between 5 to 900 k P a and maximum stress is assumed. And so, after the maximum stress, the specimen removed and again you test it for tensile test or a filtration test.

So, you are actually the thing is as I said, a damage is also should be simulated; you know, whatever is a condition that you have in the field, the movement you know, actually the geosynthetic product may be fine in the lab; in the lab in the you can manufacturing conditions will be all right. But when you are trying to use it for a specific application like a drainage or a filtration, you should be very good.

So, we have to really simulate, see the damage of the particular product; and if the damage should be simulated, there is a method of doing it as I said after 200 cycles between 5 to 900 k P a. So, we try to remove that and then tensile testing is done. So, this is what we call as a performance test.

(Refer Slide Time :25:43)

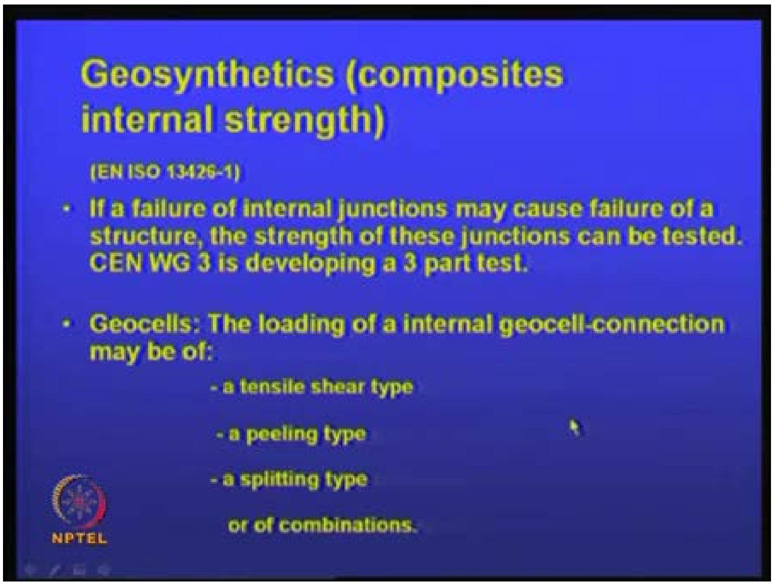


So, this is, say for example, this is like this. Damage during installation, filling up in this corundum box, this is that a geogrid material, and cyclic loading is applied and this is all geosynthetic specimen; surplus is rolled carefully outside this container during the damage procedure. So, these are all some sort of testing that is done.

(Refer Slide Time :26:11)

And once it is done, you will see the difference, like material is before you know damaged, it is like this; this is after this, damage is like this. So, people try to quantify its tensile properties or whatever properties one can find out.

(Refer Slide Time :26:25)



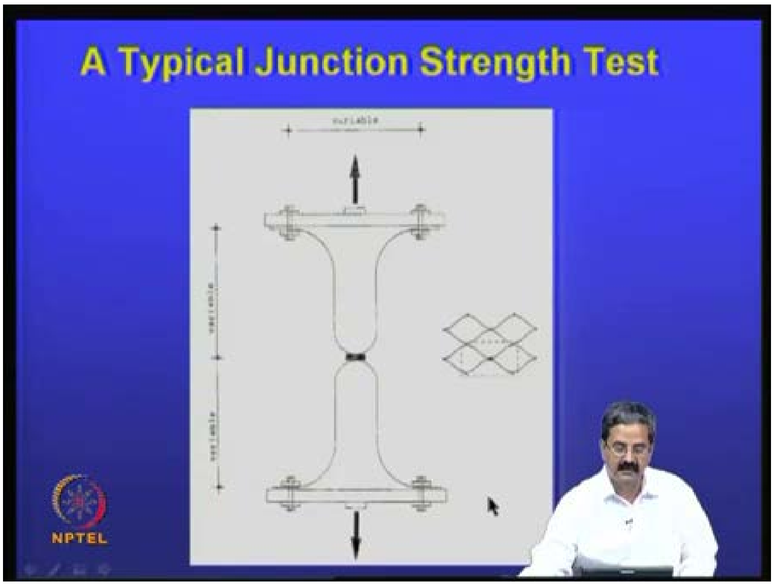
So, that is, we have some more tests like what is called for composites, particularly, when you are trying to have see geosynthetics, can also be converted into geocomposites; you can have a geotextile and a geomembrane together a combination.

So, when you are trying to combine them, there is a possibility that, if the junction, like you know, you are trying to seal them together, so if the failure of the internal junctions is likely, then it is risky. So, you have to test these junctions using some appropriate testing, say for example, geocells like as I said, geocell is a combination of you know like it has a number of a polymeric compounds, in which you can open out, it forms a geocells, but you can close it like this.

So, all at the end edges, they are all you know sealed together to form the cell; they are all sealed. So, that sealing has to be very good. So, the internal geocell connection we call it, it should to be tensile shear resistance has to be very good, peeling type you know it can be peeled off also, then splitting type it can be split also or a combination.

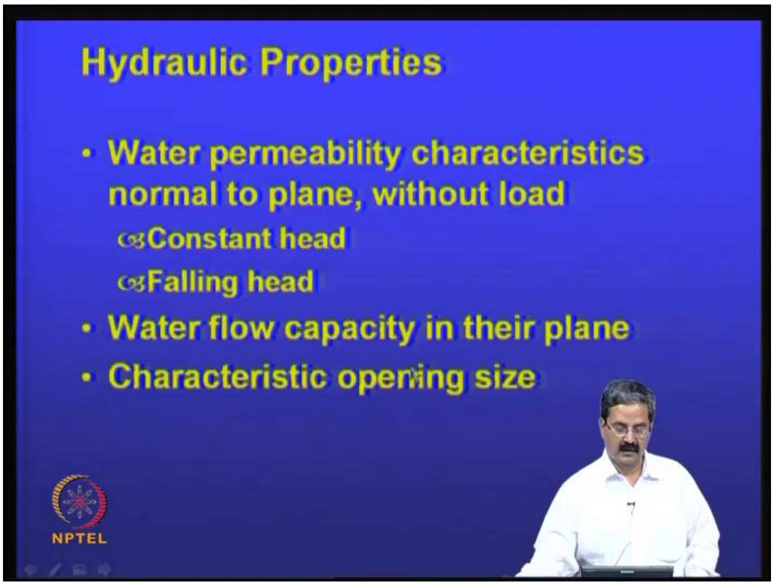
So, none of the failure should be occur.

(Refer Slide Time :28:12)



So, we try to test them for a typical junction strength; see for example, this is what I mentioned, was a geocell. So, this is what is called junction strength. So, if that is not good, then it is not going to very effective. So, you have to test this particular junction strength. So, you try to calculate that here using some the procedure.

(Refer Slide Time: 28:12)



Then another important property that we should see, are the hydraulic properties like. So, when water permeability characteristics as I said; filtration we call it, when you know the

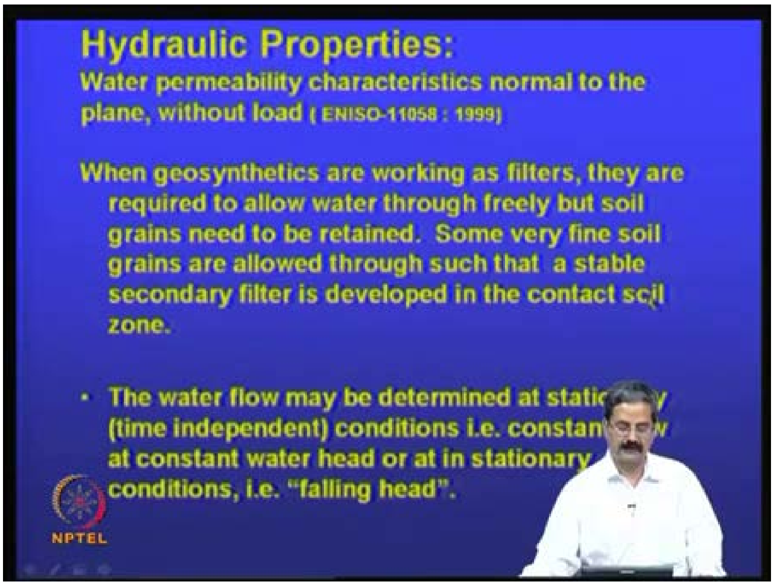
the water flow is like this, and only the water is allowed not the soil, that is called what you call filtration.

So, for this, we need to find out, we have again in a simple test, constant head permeability test, falling head type of test; and water capacity in the plane, you know, we calculate the what is its flow capacity also.

Then, there is what is called characteristic opening size; see for example, all the geotextiles have some opening size. I told you that, say for example, you take a prefabricated vertical drains, I just mentioned in the previous class for improvement of soft ground: one is a filtration characteristics, the other one is a drainage characteristic. The filtration characteristic depends on the size of the… you know; the water should only enter, it should not the soil. So, the characteristic opening size of the geotextile or the geofilter is very important there.

Then, water flow capacity; see the thing is, how much of water is it can take, what is it is drainage capacity, is another important variable. So, some of this things should be known very well, so that you can design it properly.

(Refer Slide Time :29:38)

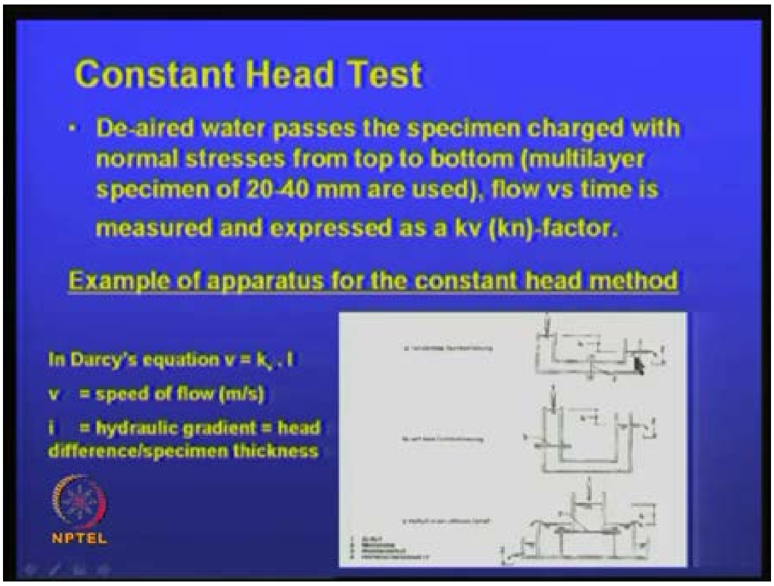


So, again we have a lot of testing procedures. When geosynthetics are working as filters, they are required to allow water through freely, but not the soil grains. So, sometimes some very fine grains are allowed through, such that a stable secondary filter is developed in the contact zone; there is a small theory for that, like, sometimes next to the filter, small particles may not go. So, they just… sometimes they go also, but there is a possibility that there is a small secondary filter that can develop in the contact soil zone, like you know, wherever that contact occurs.

So, water flow may be determined at stationary time conditions or a these are all some test depending on, you know, whether it is constant head or the falling head; one can one needs to do properly, because we should know, we should access the field hydraulic conditions, say for example, if the hydraulic gradient is not going to be very high, then, one type, you know, then it is fine; like you know, you can do a simple what is called the constant flow type of test or you know simple one can do.

But if the head is highly variable, say for example, you are trying to test the geosynthetic material at the bottom of a landfill, the landfill head is leachate head will be about set 5 meters. So, the thickness and the head is quite high. So, definitely you need to do a falling head type of tests.

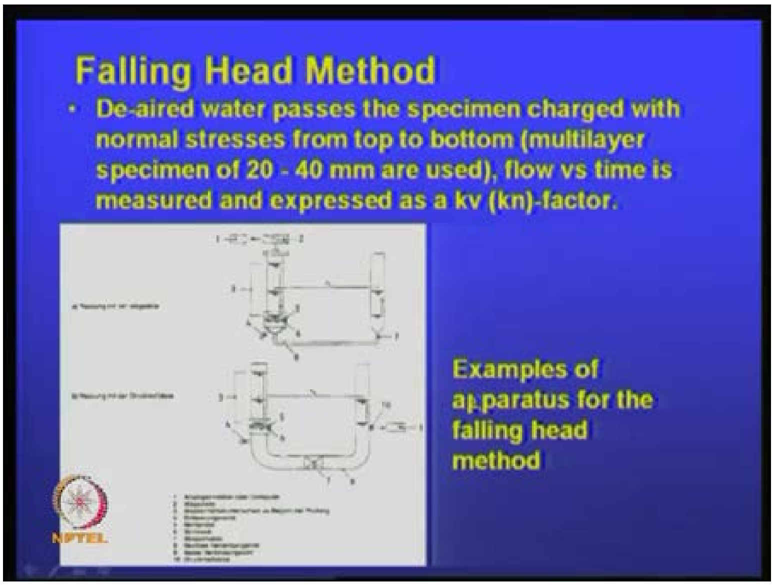
(Refer Slide Time :31:07)



So, there are some tests here, unlike what we studied; you can see that, this is a geotextile material; it is not a similar type that we know and soils. So, de-aired water passes through the charged specimen with norm; so, it comes like this and then you measure this, and this is what is called for the horizontal permeability, where geotextile is placed; this is again a vertical, this is another one that you can keep like this, vertical permeability can be measured.

So, this is another type, where you can measure, you know, the permeabilities at different gradients and all that. So, essentially, this is a simple set up that people have developed to understand what is the geotextile permeability.

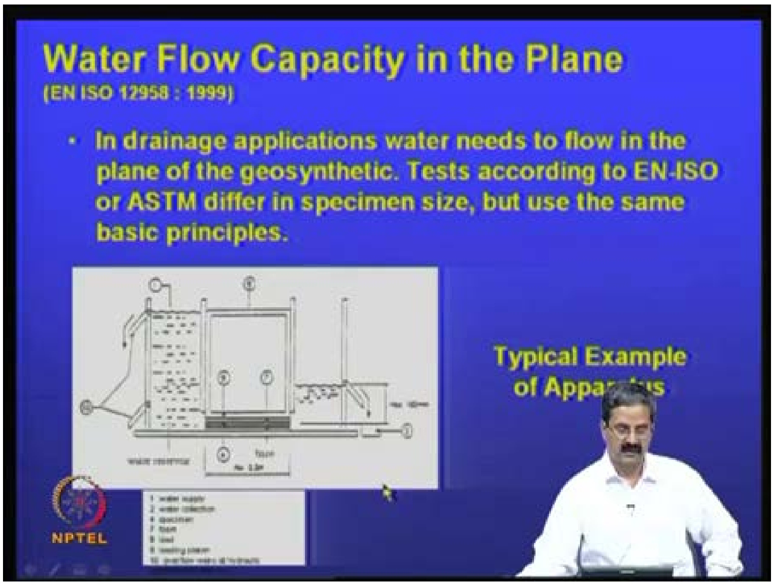
(Refer Slide Time :32:14)



So, it can be even for, you know, from flow versus time is measured. And you have that, using the Darcy’s law, one can calculate the permeability; then falling ahead again similar thing was done. Here, again a de-aired water you know, in fact, in permeability testing we should used de-aired water, because you do not want air in the water.

And the de-aired passes through the specimen charged with normal stresses from top to bottom, and multilayer specimens can be used, flow versus time is measured, and you can calculate the permeability; there are some specific equations there.

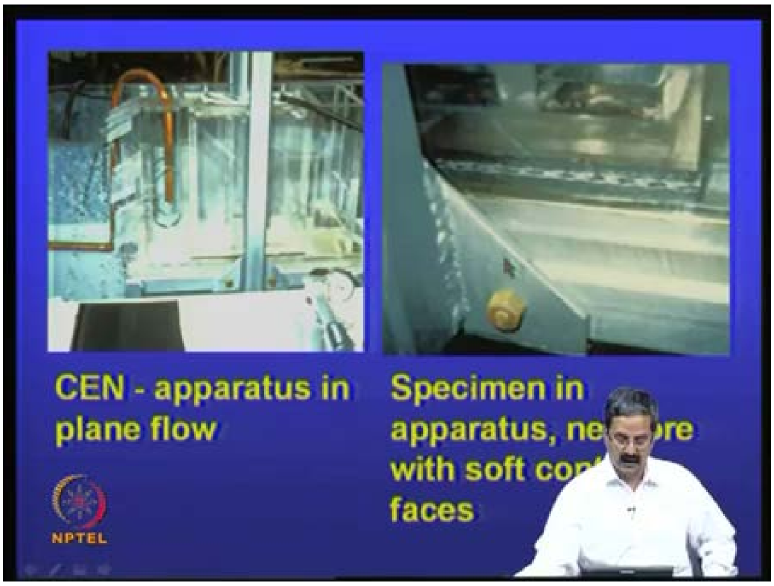
(Refer Slide Time :32:42)



There is another test which is called in plane permeability test, like as I just mentioned geosynthetic drain, I called we can call it… it can work as a drain also. So, you are trying to measure the drainage of this material; so, you have a simple set up that is fabricated here, like you know, some of this test can be fabricated in the lab also; following those standards like, you know, you have an ASTM standard, or this thing, it mentions clearly the size of the tank, the distance to be maintained, how do you place the material, how what is the clean procedure and all that; they mentioned everything.

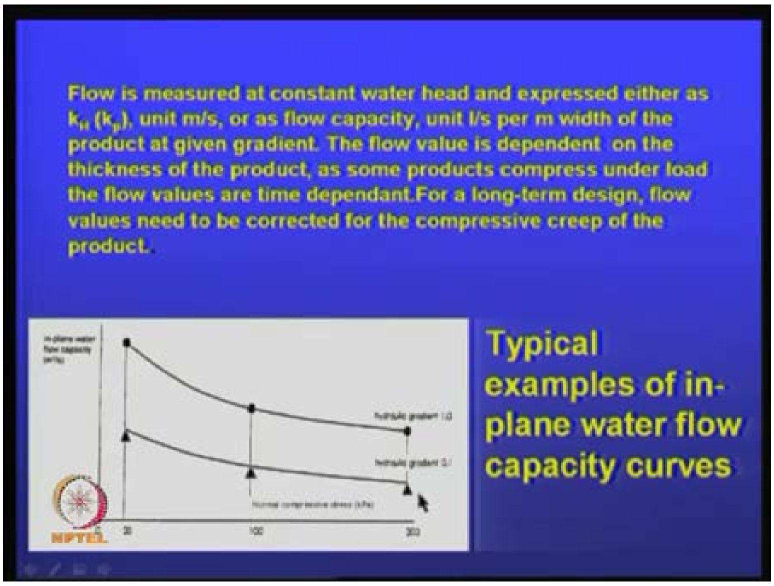
So, you can follow the same test procedure and use it for a geocomposite here you know. In fact, geocomposite can be placed here and then you can measure the drainage capacity. So, water flow is what you are trying to find out here.

(Refer Slide Time :33:35)



So, this is the type of test, for the in-plane flow test; this is a specimen in apparatus, net core with soft contacts. If this that you can see that very clearly, that geocomposite net core net, geonet is nothing but a drainage material. So, they have placed that material here and then they are testing it; this is a very important thing.

(Refer Slide Time :34:09)



So, flow is measured at constant water head and expressed either as permeability in meters, or the flow capacity per unit width, like you know, per width at a given hydraulic gradient. So, for different hydraulic gradients, we can get this material. So, the flow is dependent on the thickness of the product, as some products compress under load and the flow values are time dependent.

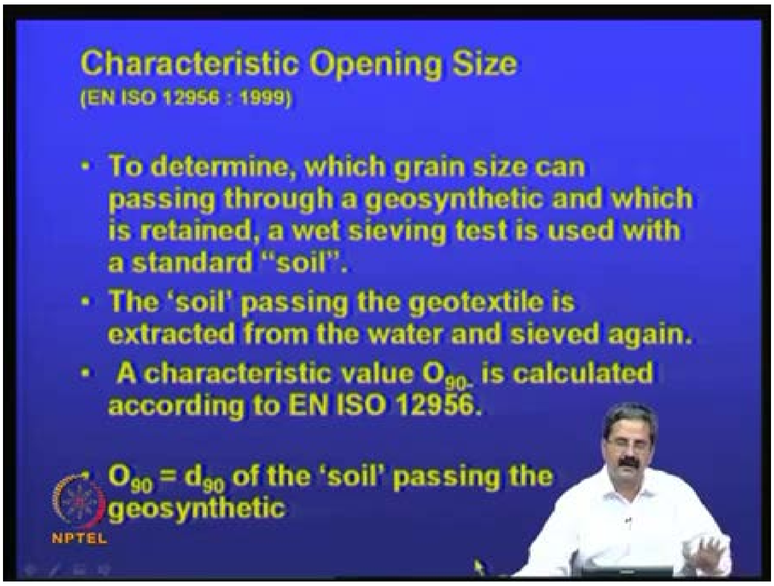
So, for long term design, flow values need to be corrected for the compressive creep of the product. This is very important as I just mentioned like, in fact, I did couple of test on this type of material, where for a coir drain that we developed, we are looking at its in-plane capacity, because in a coir drain, its drainage is very important and. So, we have to measure the compressive the water capacity you know in-plane water capacity how much of water it can take under different pressures like 20 k P a 100 k P a and 200 k P a.

Because say for example, in the coir drain I am putting for say 10 meters deep, 10 meters means it is a considerably deep; at 2 meters, the pressure is two into, say for example, twenty; so, 40 k P a, and at 10 meters, it is 200 hundred k P a. So, it must be able to see the drainage function satisfactorily.

So, I must be able to see that, there is at the in-plane adequate in-plane flow is there all the time; that is what I just want to say. And as I said, it is also a function of the hydraulic gradient; if higher is the hydraulic gradient, higher is the in-plane flow. Like if you have a good gradient, definitely there is a good water flow. So, that also you should be measured, because you must have an idea of what is a hydraulic gradient that one can expect in the field.

How do you get this? You have the information from flow nets and seepage and all that, like you have to do a really a flow analysis and you should know how much of head of water is acting; and say for example, you have a dam, dam you want to. So, you can calculate for a dam, what should be the drainage required, you know, so that, so all that one can make calculations; essentially, I would like say that, the drainage is an important parameter; it is a function of the material, size, thickness and although the load applied.

(Refer Slide Time :36:40)



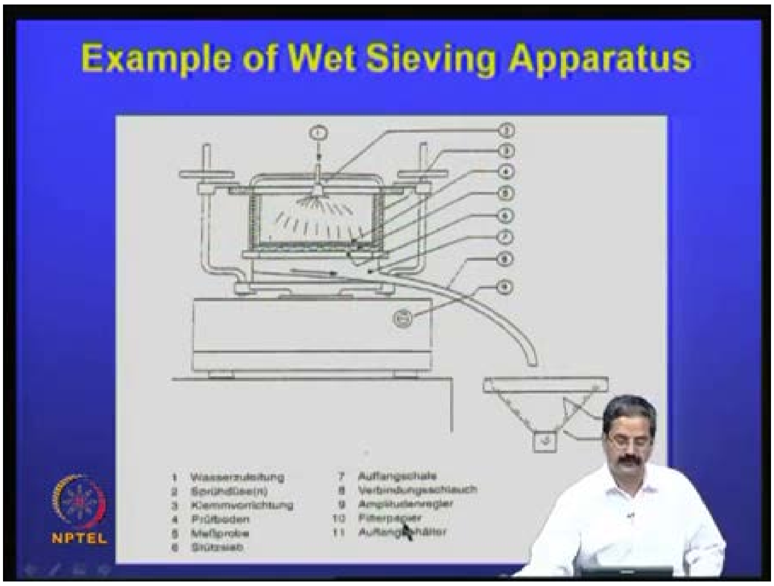
As I just mentioned the apparent opening size or the size of the geotextile is another important parameter, like, see, we know, we we design the filters based on gradation size, we say d 60 size d 10 size d 30 size and all that.

Here, we try to calculate what is the characteristic opening size, which is nothing but it is its 90 percent of the material can pass through that. So, to determine which grain size can pass through a geosynthetic and which is retained a wet sieving test is used with a standard soil.

We take a standard material and pass that the standard material, say for example, you have different glass balls of different sizes, say for example, 0.1 size 0.01size, 0.05 size and all that, you try to pass through the geotextile, and where 90 percent of the material pass through, you can designate that o's that size corresponding to that 90 percent as the o 90 size.

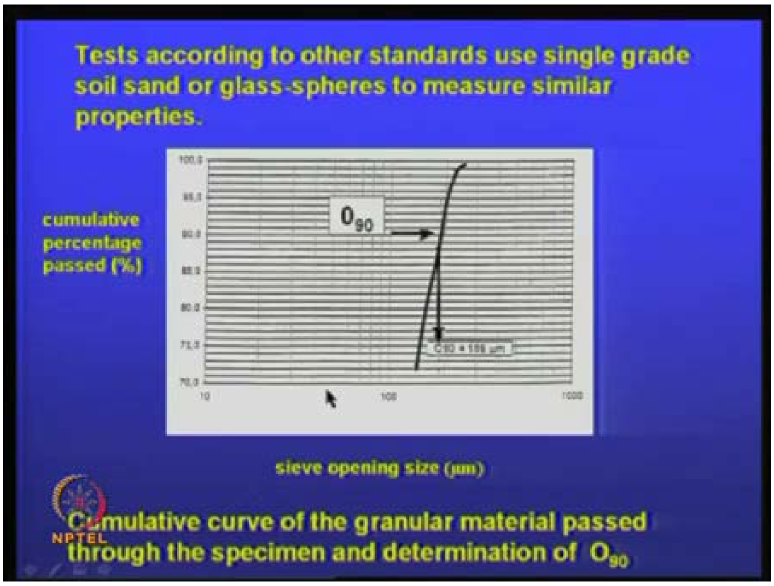
So, o 90 is nothing but the d 90 of the soil passing through the geosynthetic; it is very clear that, you have any material which has some small, it can be 0.01 only, but you try to do a proper analysis like this, that becomes a o 90. So, because this is very important to define the filtration criteria in a geosynthetics; we will see that later.

(Refer Slide Time :38:11)



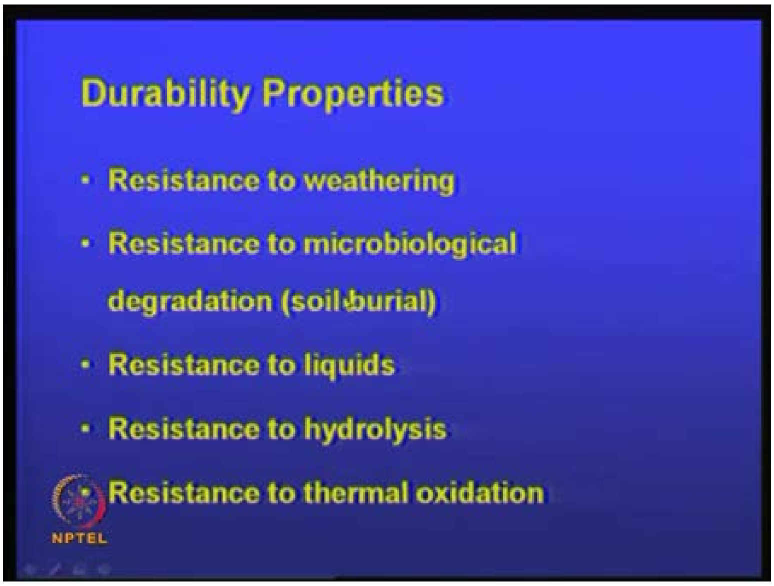
The way the test is done is like this, like you know, you just put water and try to calculate, and you know, different sieves are there; of course, this is all in German and because this is a material that we get from them.

(Refer Slide Time :38:25)



And this is how it is done cumulative passing, you know, say for example, you have a different 70 to 100. So, you can see that, o 90 size is this size. So, so this is a very important one that we will be using later. So, tests according to the other standards use a simple gradation grade characters are glass-spheres to measure similar properties. As I just mentioned you can have sand also, fine sand also or a glass-spheres, right, to measure the properties. So, this is how we get it.

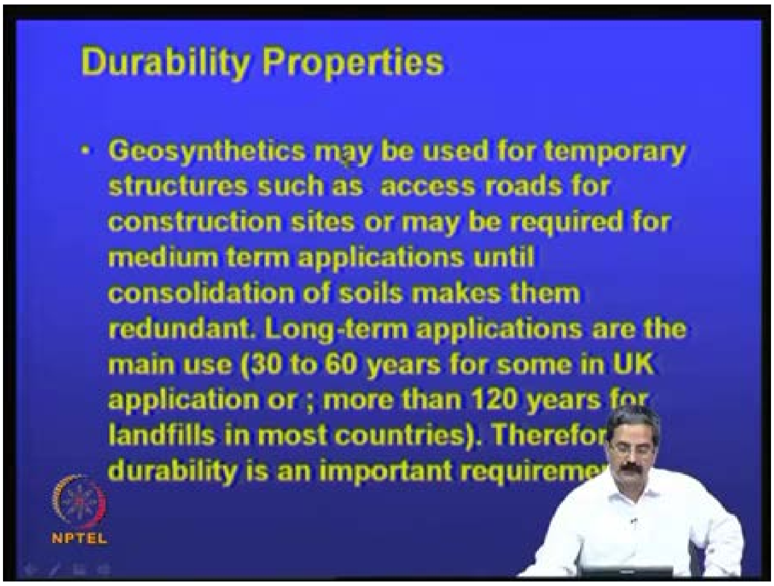
(Refer Slide Time :39:00)



Another important point that we should say is that, is that material durable; what you saw earlier was, first is mechanical properties we have seen. First is, we have seen how the material is identify, the second one is mechanical properties, third one is hydraulic properties and then durability properties. Actually, we have all you have also seen endurance properties, like you know, number of cycles; it can go like, you know, abrasion tests and all that we have seen.

After that, durability is another important issue that we should see, because if the geosynthetic materials are not done or do not exist, say for example, 30 years, then it is risky; you cannot use them, because our life cycle, you know, we are trying to design buildings for about 50 years.

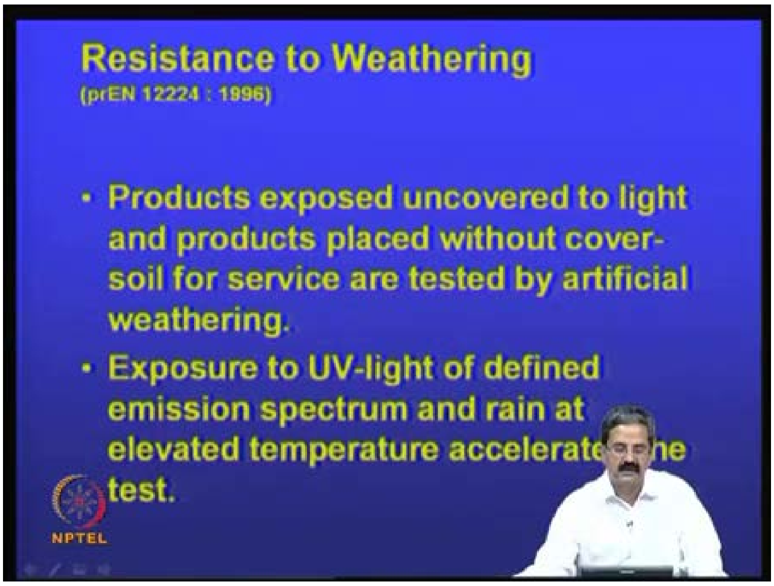
(Refer Slide Time :39:52)



So, you need to see resistance to weathering, resistance to microbial degradation, resistance to liquids, resistance to hydrolysis, the resistance to thermal oxidation. So, actually geosynthetics may be used for temporary structures such as access roads for construction sites or may be required for medium term applications, until consolidation of soil takes place and redundant.

Long term applications are also used like, 30 to 60 years and 120 years also. So, we have to see our material, we are taking is it good for short term, medium or long term; one should be very clear on this, then you can use it.

(Refer Slide Time :40:22)

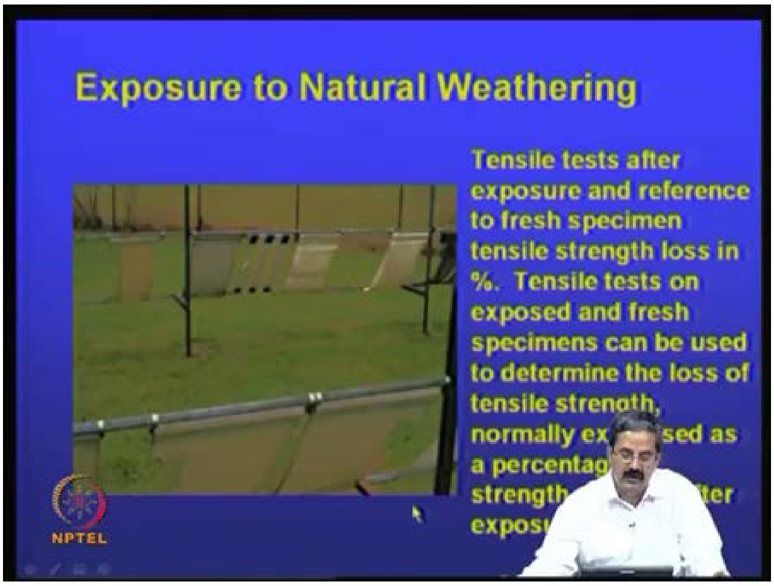


So, you can find out its corresponding property and do that. So, resistance to weathering: what is that, it is essentially that, the products exposed to uncovered light, you know, if you do not cover them properly, the possibility is that they are exposed to ultraviolet rays; and the possibility is that, it gets… see the thing is, you just leave, you know, I have seen you just take a geosynthetic material and leave it outside.

The initially it is nice, but then after that because of the ultraviolet rays exposure, whatever is a sunlight exposure, it gets very stiff and all that; after that, you can just break it also with hand. We have some materials in our lab, where you just leave it, if you do not take care of them properly without proper you know coverage and all that, then or you have to store there is some requirements for storing.

You just, so, we have to store them properly and remove them, and then put it in the soil. So, put you actually, it will not, if you expose it, it gets degraded, but if you it is in soil, then there is no problem. So, ultraviolet test is one thing that we do.

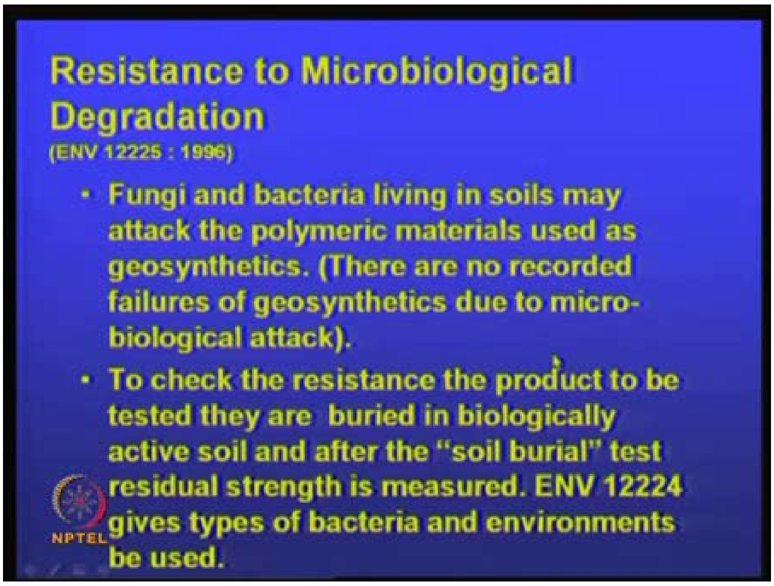
(Refer Slide Time :41:27)



Then, there is a what is called exposure to weathering. Tensile tests after exposure and reference to fresh specimen tensile strength loss is there, like you know, you expose it to different tensile testing I mean different degrees of weathering here, like keep the samples for 1 year 6 months, I mean, like normally say for example, a phd program definitely that person can test for two and half years, like immediately as soon as it registers take the fees and then put it like this like.

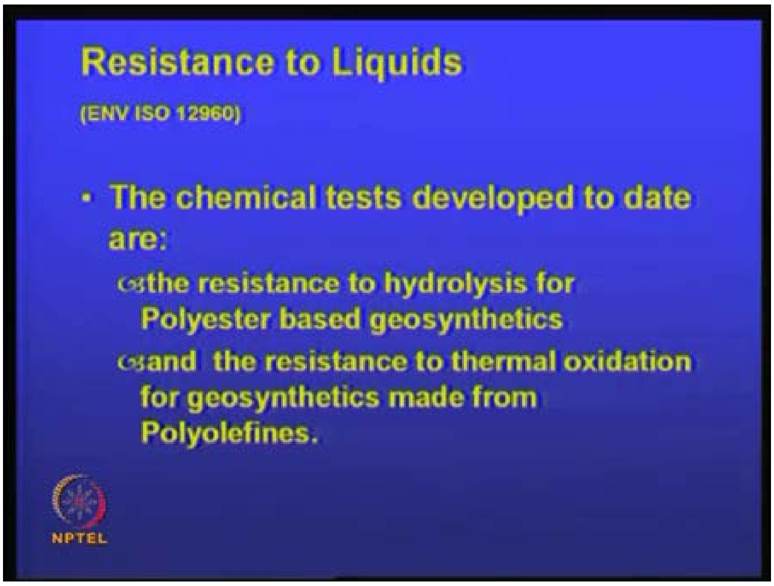
So, that is what people have done it in a earlier case also, or put in the soil and then see its tensile strength and all that because they give some information. And we have to compare with what is immediately, you test that, you get that material; you will have some number, like say for example, 40 kilonewton per meter, then you leave it for a one week or a one day or something, then what is the tensile strength is? So, you have to really do some testing here, which is very important.

(Refer Slide Time :42:23)



Then, you have what is called resistance to microbial degradation like, fungi and bacterial living in soils may attack polymeric materials used as geo-synthetics. And of course, you know there is some test, that like the advantages that we bury them.

(Refer Slide Time :42:53)



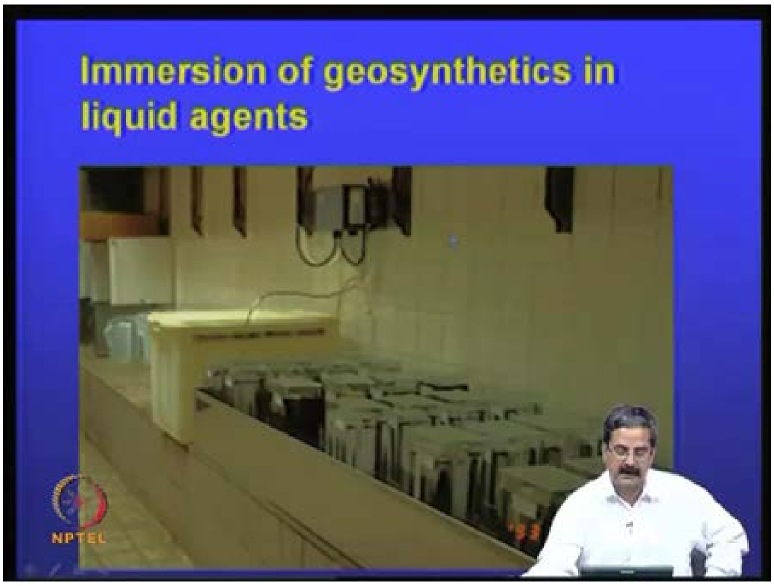
So, the exposure to outside thing is less, but even there is a possibility that some microbial organisms could attack. So, that needs to be examined, of course, we do not have a, we have a test for that. The test gives a different types of bacteria and environments to be used. So, we have to essentially follow these tests and whatever it reports is fine for us.

Then, there is some materials that are, you know, one should identify, say for example, if you are using a geomembrane, see there is a company that is generating lot of waste liquid. And you want to store the waste liquid, you know, you cannot allow the waste liquid to get into the soil, right. You have to protect that, see the soil, protect the soil. So, you need to have some sort of a geomembrane system, you need to develop a waste containment system having a geomembrane.

And that geomembrane should not get affected by any of the chemical processes, say for example, the hydrolysis test, say for example, if you have polyester based geosynthetics materials, there is a possibility that hydrolysis occurs. And this material like a polyester material may get degraded. So, there are some specific test for this and say for example, you take polyolefines; so, they have a problem with thermal oxidation, like you know, when there are subjected to atmosphere conditions, because of the oxidation and temperature, the tensile strength will come down.

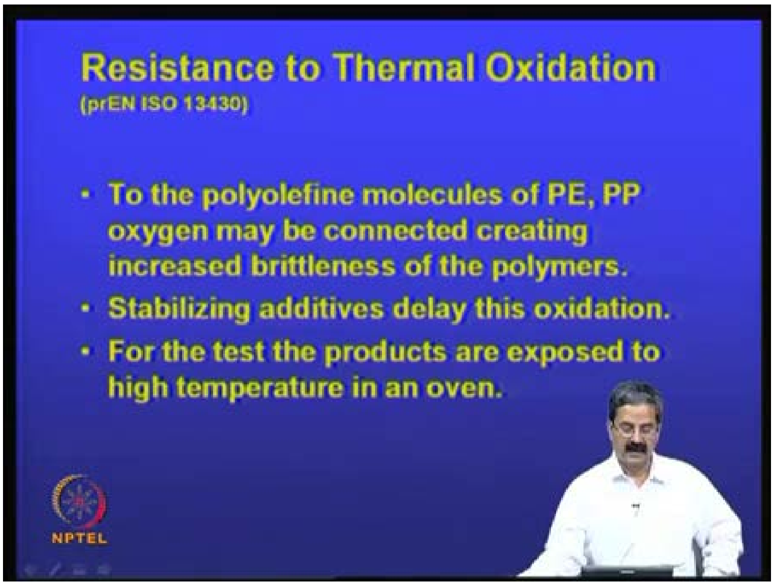
So, you have to find out some of these weak weaknesses of this geosynthetic materials, whether in chemical conditions or environmental conditions, and see that such conditions are not encountered. Of course, the conditions are not easy to overcome, but you have to choose a material that will not have difficulties, when you have this type of conditions.

(Refer Slide Time :44:42)



Say for example, what people do is that, they try to put the same material in different containers in different liquid agents, and test them at different times; this is one type of test, in which one can identify their properties; this is one simple test.

(Refer Slide Time :45:01)

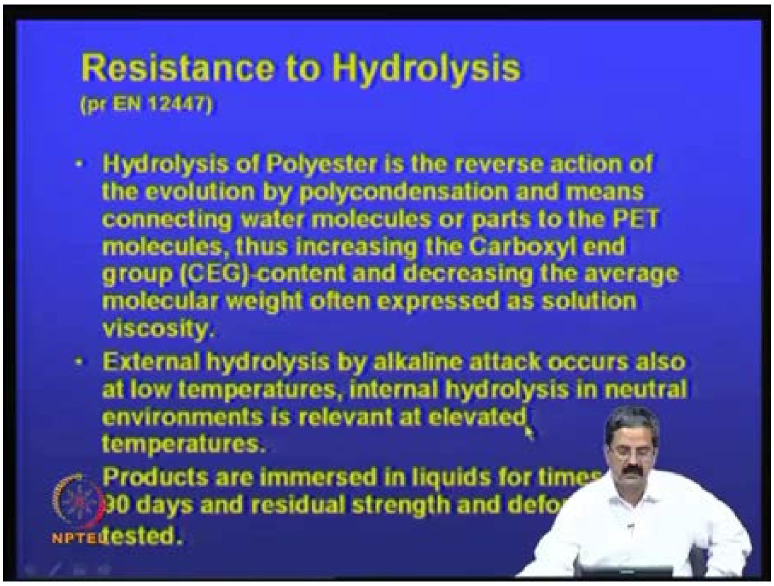


Then, resistance to oxidation as I just mentioned, to the polyolefine molecules of polyethylene, polypropylene, oxygen may be connected creating increased brittleness of the polymers. As I said, brittleness is one thing that can, you know, because of the oxidation, it can just the material what is soft, it can just after that, it becomes wrinkles and becomes stiff and all that, and if you touch it, it gets broken.

So, what we do is that, we have some materials called additives - stabilizing additives. So, the moment you know that there is problem with this material, so you have some standard additives that will delay this oxidation.

So, you need to have some sort of admixtures like, you know, you have in admixtures in concrete, you have to do this. So, for the test, the products are exposed to high temperature in an oven.

(Refer Slide Time :45:50)



So, this hydrolysis is again is something, that hydrolysis of a polyester is the reverse action of the evolution of polycondensation and means connecting the water molecules or parts to the PET molecules, thus increasing the carboxyl end content, and decreasing the average molecular weight often expressed as solution viscosity.

Actually what we do here is that, this hydrolysis is something that is another serious problem in many of the polyesters. So, we have to take care of this and you need to create a proper conditions, say for example, why those things happen is that, see, because of this presence of, due to this hydrolysis, the average molecular weight will come down actually. So, there are some couple tests that are done.

(Refer Slide Time :46:47)

So, what we do is that, the products are immersed in liquids for times up to 90 days and residual strength and deformation are tested. So, you have a number of tests in this manner, and what we do is that, we have number of testing procedures, which are well established.

And so, what I would like to mention is that, the geosynthetic the materials you are using it for mechanical properties and then hydraulic function, say for example, we know that the functions are the geosynthetic material or reinforcement, filtration drainage, then moisture barrier separation. There are so many properties that we studied as their functions.

One should really use a proper application; you should understand the application and also get that property also properly, like, I have seen a case, where a geogrid was used for erosion control; geogrid we know, we use it more as a reinforcement. So, if use so, whatever material you are using it for erosion control has to be exposed, means, see erosion is nothing like, you know you put a simple geotextile and because of the atmospheric conditions, you know, whatever, for example, take the case of a steep slope seventy degrees or sixty degrees slope, and it is subjected to erosion, like because of the rain water and all that, erosions are formed.

So, if you use a natural material, like a jute geotextile or a coir material, the advantage would be that, coir is cheaper and jute is also cheaper; and if you put that materials, what happens is that, and then actually initially you have to put that nice seedings, you have to put some seeds, then put this cover.

And because of the atmospheric action and all that, though there are this jute and coir are suppose to be biodegradable, they just you lose their properties within one year. But then, within one year time, actually what this material does is that, because of this, you know, you stitch the slope with a geotextile, erosion will not come. And at least for one year, and you also have within that one year, plantations that grow up; when the plantations grow up, then there is a then the erosion will not occur. So, that is a beauty.

So, you need to understand that the, so for that, you know, the type of testing required is somewhat different, say for example, you must be able to find out the properties of the coir material, say for example, it is tensile strength and how long, say for example, a six months what is its tensile strength, and one year what is its tensile strength and all that.

The other important point that I would like to highlight to you is that, there is a tendency for using, see as I just mentioned in the case of a geogrid for erosion control, in we have seen where it was not efficient, why? Because after one year, it formed wrinkles and all that you do not need to use that material there, for erosion control; a coir material would have been ideal.

There is another case that I would like to mention, that the geotextile was good enough, because geotextile can take more deformation, say for example, in a like we have seen that geotextile can be used for protection layer, right. So, geotextile layer could be used for protection layer what it means is that, if you put sometimes load also, it can just deform a bit, like you know, it form a bowl and it is a whereas a geogrid is not, it cannot work.

So, I have seen one application again where geotextile should have been ideal, but they use a geogrid. So, they actually they did not understand that, geotextile can hold that material for longer time compared to a geogrid, where geogrid you know soil is allowed, it is the function there was to allow this retain the soil and allow only the water.

And also allow that weight, you know, some sort of deformation is also required there. So, there geotextile should have been ideal, but then… So, like that, so one needs to a have a good knowledge of the geosynthetic testing procedures, because you should know that, their properties how they vary with time, temperature; you know, in many of these materials or polymeric materials, they will have a changes with time and temperature.

Time and temperature and humidity and all that; so, environmental factors are quite important. If you have a good idea, you can get, you can really know choose your numbers properly, like you know, say for example, you need, see, you are constructing a retaining wall for about say 50 years and you need the tensile strength to be maintained up to 50 years, so, you can use, you can go to the company, ask a geotextile geogrid material which has, say for example, 50 kilonewton per meter. Then, apply all these correction factors, like which will account for mechanical damage, then environmental factors and all that, creep and all that, they come from testing only. All these correction factors come from testing, like we call them, say for example, partial factors of safety in structural design, we are familiar.

Here also, if you want to use it is called material partial factors, you have to get them by extensive testing and analysis. And once you get those correction factors properly for the time intended, it is fine.

So, durability is another important point you should be understanding that, because our objective - final objective - is to ensure that this geosynthetic material you are trying to introduce and you should see that the, say for example, you are using for a landfill application. If it does not solve the landfill application, then there is no use.

Like stability is another important point, because you are trying to improve the stability, and landfill should be safe and all that; so, one should ensure the stability as well. So, this is an important aspect in the geosynthetic testing - the geosynthetic materials itself.

So, with this, we will move on to the other things which are quite important.

Thank you.