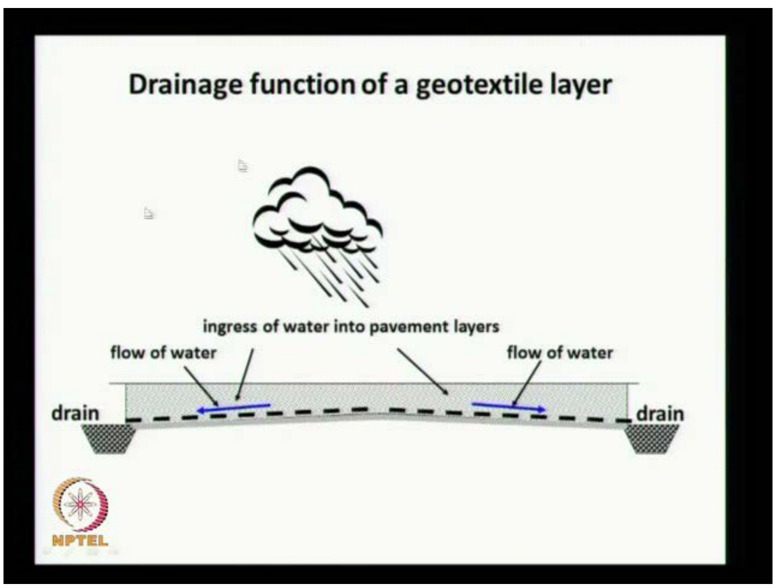
Geosynthetics And Reinforced Soil Structures
Prof. K. Rajagopal
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 35
Drainage Applications of Geosynthetics

So, very good morning students. In today's lecture let us look at the drainage applications of the geosynthetics. This is one of the most important applications as far as the soil structures are concerned, because we know that the soil itself is very strong, but when there is lot of water that is stagnated inside the soil. We know that the soil will not be able to function properly because of the excessive pore pressures that are generated then the possible liquefaction, piping and other phenomenon that may happen. So, it is very important that we provide for sufficient drainage, so that any water that enters the soil is safely led away from the structure.

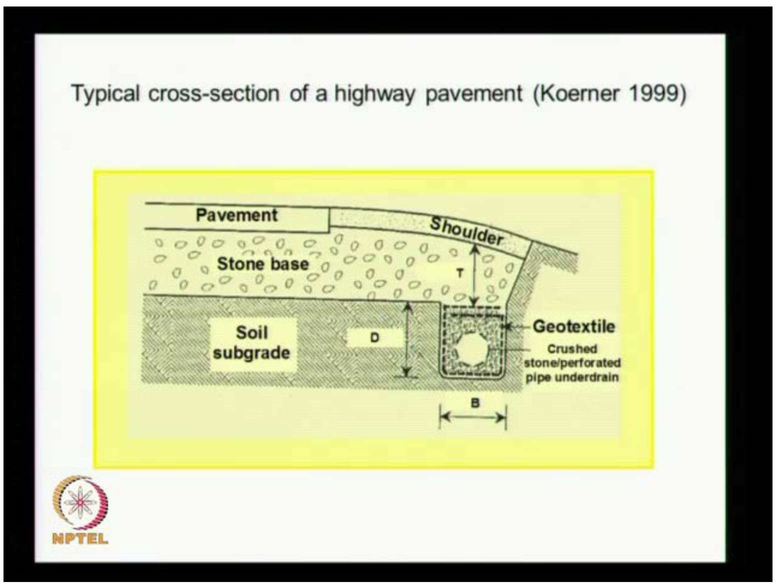
(Refer Slide Time: 01:02)



And typical illustration of the drainage function is shown here. Let us say that we have a highway pavement, and in spite of the fact that the surface is treated well with ashfault or bethermen, there could be some leakage through which the water can find its way into the pavement layer. And if we allow the water to propagate further, it will enter the sub drain and it reduces the strength and the stiffness of the sub drain. And so we need to make sure that whatever water enters the pavement is safely led away into side drains.

And usually we do that by providing granular subways and other aggregate layers, which are highly permeable and which are usually provided with some gradient leading towards the side drains and with the advent of the geosynthetics, we can even think of providing a geosynthetic. In addition to our aggregate layers because the aggregate layers, they may tend to get clogged during the service life. And so the flow through the aggregate layer may not be possible all the time whereas, the geo textiles they are factory produced. And so we can always choose a product that will have a good sufficient design life.

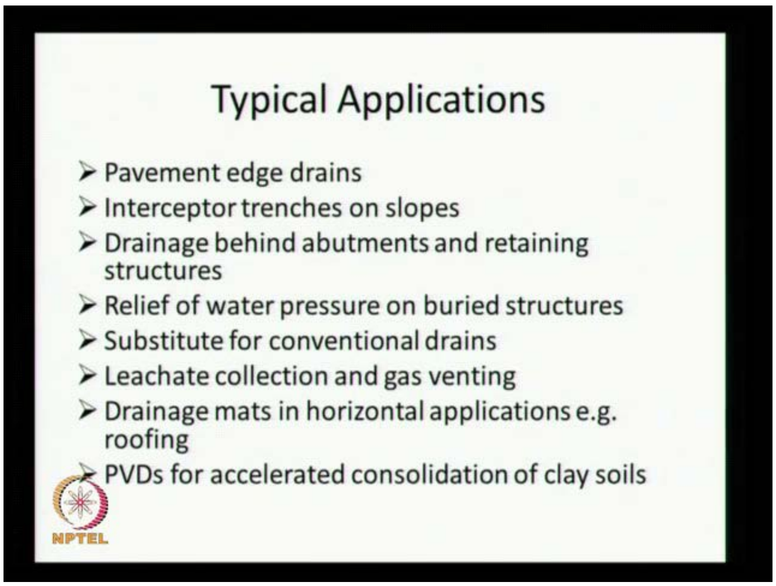
(Refer Slide Time: 02:49)



And the same pavement application is illustrated in more detail manner by Koerner in his text book that was published in 1999. Here we have the pavement then we could have a shoulder and we have a stone base or aggregate base then we have the soil sub grade. The purpose of this stone or aggregate base is to provide a stiff base for our road surface. Then also provide for drainage to lead the water into the side drains. And at this drain itself it could be an open gutter like in most of the Indian highways or it could be a trench drain that is buried in the ground.

And that instead of having an open gutter, we could have it filled with some graded aggregate and may be inside we can also provide a perforated pipe. In order to prevent the clogging of this drain with fine particles, we could even think about providing a geotextile wrapping. And whenever we do this, the cross sectional area of this drain, it should be properly designed so that it can cater to the expected run off. So, the cross sectional area of this drain consists of the height and then the width. And that we will see in one of the examples.

(Refer Slide Time: 04:21)

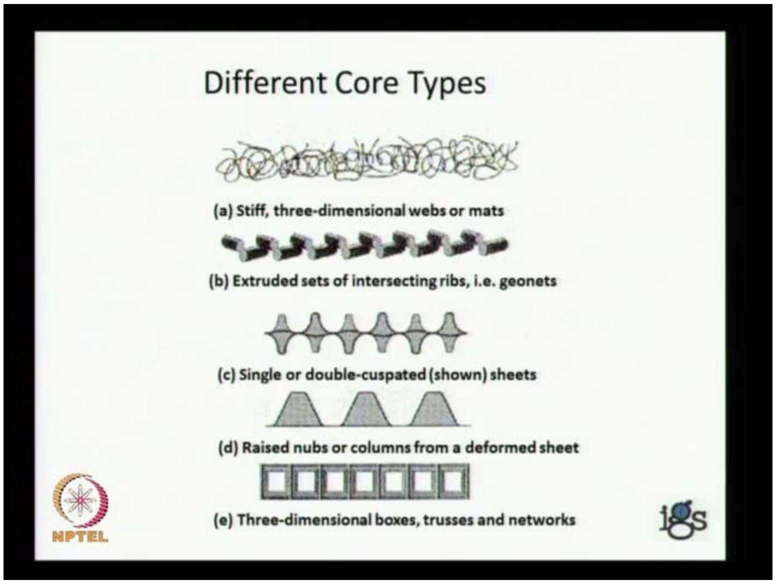


And what are the typical applications for the drains. Well one example that we have just seen is the pavement edge drain or we could have them as interceptor drains on the slopes or drainage behind the abutments and retaining structures. This is a very important feature of any of the retaining walls. From our geotechnical engineering, we know that the lateral earth pressure coefficient for most soils is made about 0.3 to 0.5 whereas, for water it is 1. Say if water is stagnated behind the retaining walls or abutments the overturning moments.

Then the lateral forces on the retaining walls they exceed tremendously and which may or may not have been considered in the design. So, it is very important that we do not allow any water to get stagnated behind the retaining wall for a long time and relief of water pressure buried structures. Just imagine that we have a very good textile or some aggregate layer and that could provide for fast dissipation of any pore water pressures that are developed. And that could act as a relief wall for the pore pressures to get dissipated.

And these geosynthetics can be used in place of our conventional drains then of course, in the landfills we need a good leachate collection system, and then a good gas ventilator to collect the gas and then lead it safely to some incineration point or some other collection point. Then we can also use these geosynthetics as drainage mats in horizontal application that is in the case of roofs or in the flooring and other things. And earlier we have seen the application of the pre fabricated vertical drains for accelerated consolidation of the soils, that is also one typical drainage application.

(Refer Slide Time: 06:40)



And as we have seen with the PVDs earlier, these drainage materials they consist of a filter layer that is surrounding the inner core and the inner core provides or serves as the drainage medium. There are different types of inner cores that are possible. We could have a crimped mesh or a three dimensional web or mats like this or we can have a set of extruded intersecting ribs like this which is typical of the geonets.

We can also have the cups something like this which are just simply projections on a sheet of plastic sheet. Then we can have the raised nubs or columns of a deformed sheet or we can have a three dimensional box structure that can act as a drainage medium. All these cores they act as drainage mediums and then around surrounding these cores, we have geotextile that can act as a filter.

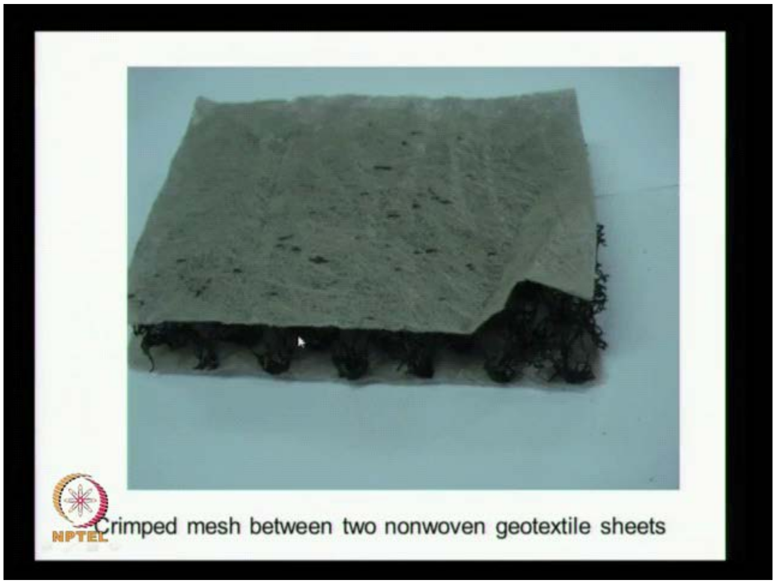
(Refer Slide Time: 07:49)

And here we see an example of a say geotextile surrounding a geonet and this could act as an excellent drain, because the geotextile here that is surrounding, the geonet can act as a filter medium and the geonet can act as a good drainage medium.

(Refer Slide Time: 08:11)

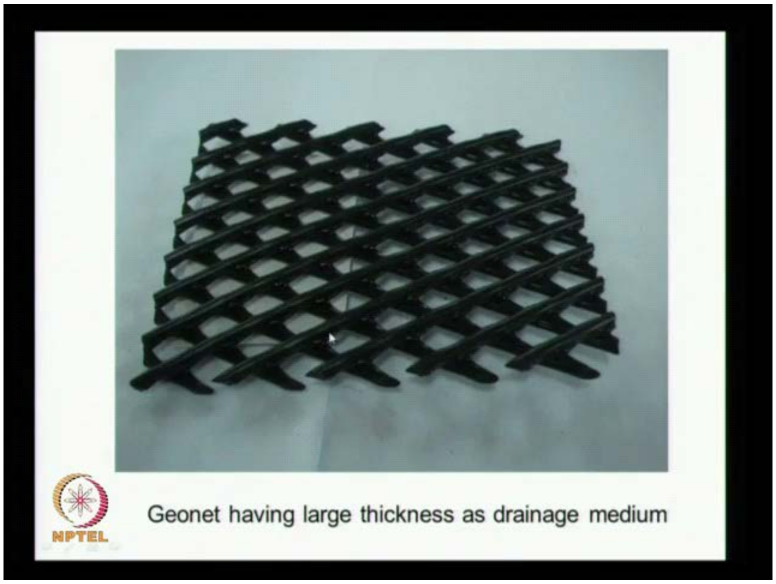
Here we see the recycled rubber being used as a drainage medium. These are all crimped or cut pieces of rubber which are joined together loosely, so that they have a very large void space and any water that enters here can easily flow because there is a large void space.

(Refer Slide Time: 08:35)



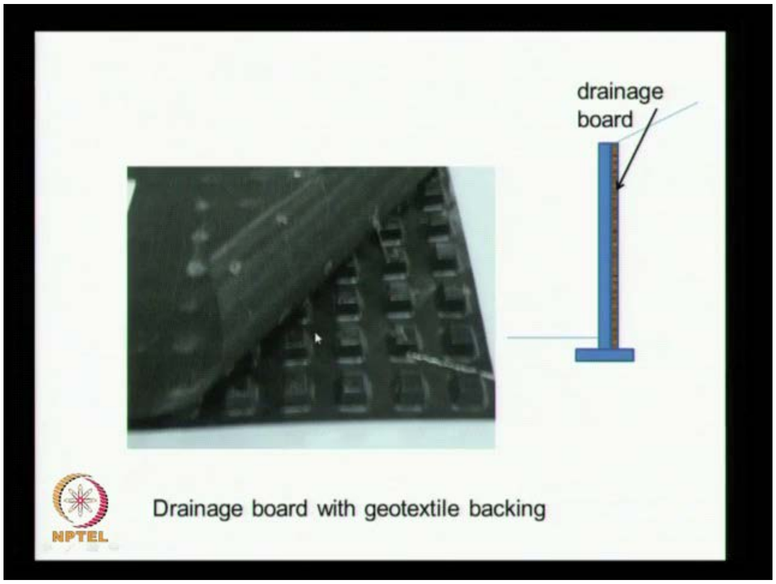
Here we have a another drainage material that is consisting of a crimped mesh as an inner core and geotextile layers surrounding it that act as a filter medium.

(Refer Slide Time: 08:52)



And here we see detailed view of the geonet. The geonet just re-emphasize once again, which is not to be considered with the geogrids, because the geonets they are more like a geo spacers. These ribs that are there in the geonet they are in two different planes, that means that they have a very large thickness as compared to geogrids. And the junction strength or the tensile strength of these geonets is very small because they are not used for reinforcement purpose, but they are only used for drainage purposes. If we burry this in the soil, water can easily find a path along the geonet because the soil inside these openings is not compacted sufficiently as compared to the surrounding soil. And so the geonet can act as a excellent drainage material.

(Refer Slide Time: 09:59)

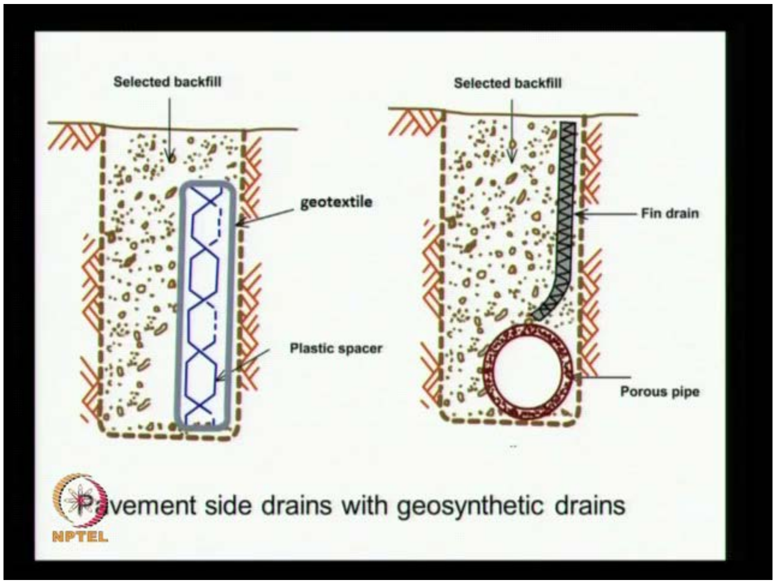


And here we have a typical drainage board that is specially developed for applications in the retaining walls. Here we have a plastic sheet with some cups or the projections and then on the top, we have a geotextile covering, and we take this drainage board and stick it to the retaining wall like this with the geotextile facing the soil. And so that any water that is there in the soil can freely flow into this drainage board. And because of the open nature of this core the water flows down through the drainage board. Then at the bottom we could have a collection pipe or we can have some weep holes through, which the water can find its way out of the retaining wall.

(Refer Slide Time: 10:59)

This is another very innovative application of recycle materials. This is the drainage medium is made of expanded polyester in beads and EPS. We have seen earlier that it is a very light weight geofoam that can be used in several geotechnical constructions and one such application is there in the drainage medium. And because all these EPS beads, they are loosely bonded together, there is a very large open space. Depending on the size of the gas beads or the EPS beads that we use, we can control the porosity of this medium. And it can be designed to serve as an excellent drainage medium.

(Refer Slide Time: 11:49)

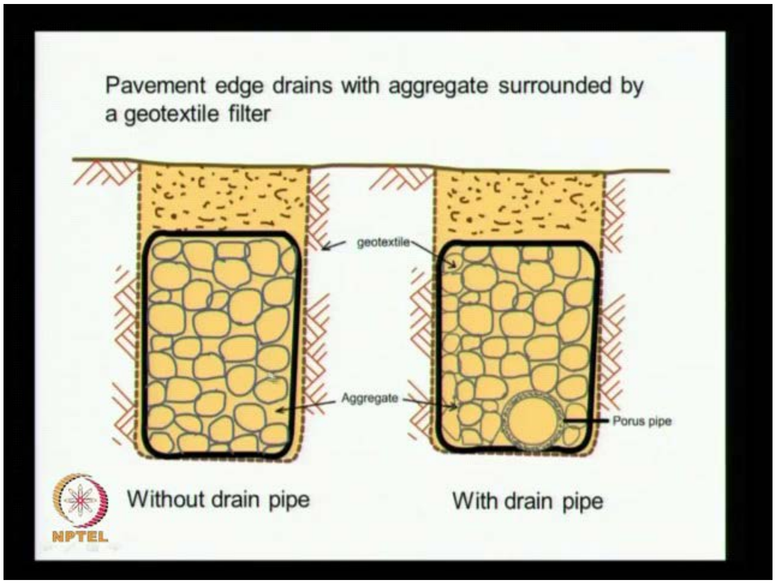


Here we see typical French drain the pavement side drains. The one simple thing is we can fill this entire the ditch or the drain with graded aggregate, that can itself serve as a drainage medium. In some cases we can put a geosynthetic drainage medium that consists of a core and a geotextile filter, and that can substantially increase the drainage capacity of this the pavour drain or we can have a perforated pipe at the bottom. We can lead the water into this perforated drain through a fin drain which is similar to our PVDs.

So both of them can act as excellent drains because these drains they are filled with the graded aggregate, that can have a very large porosity and wide rashes so that they can act as good drains. The main advantage with these drains as opposed to the open drains or open gutters, that we have in India is open gutters invariably. They serve as receipt tackles for the garbage that is thrown on the road, that is one very bad habit that we have in India.

We fill any open area with garbage and because of that the consequence is the roads do not have the sufficient design life, because although they are designed well they do not survive because of the pore pressure that are developed below the road basis, because we are not allowing for drainage of the water below the pavements.

(Refer Slide Time: 13:49)



Another form of the paver drains are shown like this. We could have an aggregate fill and that is covered entirely with a geotextile filter so that the drainage medium is not contaminated or fill with fine aggregate or the fine soil particles. We can also have a porous pipe or perforated pipe. So, these are two different possibilities this is without a drain pipe and this is with a drain pipe.

(Refer Slide Time: 14:26)

.

Here is another example on how we can utilize perforated pipe. Here we see a perforated pipe covered with a geotextile. And here you see another close up, we have this PVC pipe with perforations. We need to cover it with some geotextile so that this pipe does not get fill with fine soil particles or wet clogged. Once these are fabricated, they can be laid along the drains at some depth, to provide path for water that enters the pavement that to escape from out of the soil structure.

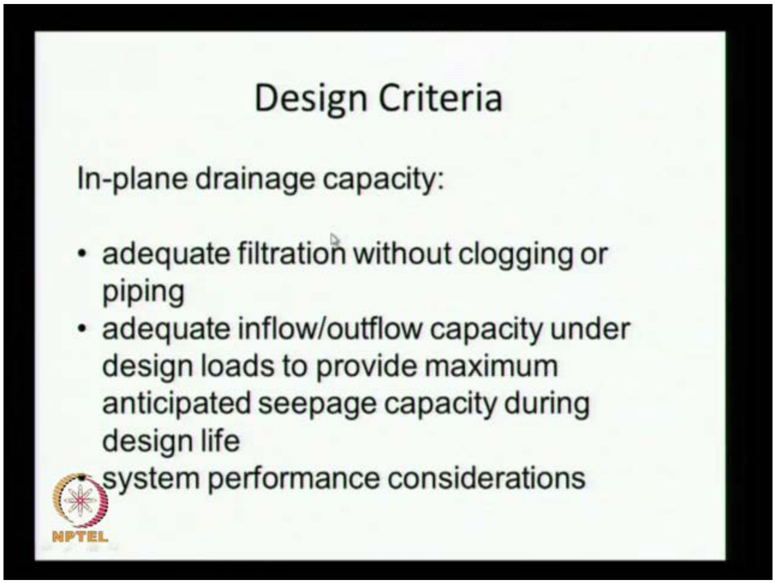
(Refer Slide Time: 15:10)

And here we see the application of a geosynthetic trench drain. This is to provide or to trap any water that comes through say for example, there is a canal here and if you provide this interceptor drain, this water cannot or will not flow into the surrounding. And if you provide these drains on a side slope or on hill slopes, we can catch the water that enters the ground and safely lead it away from the critical points.

(Refer Slide Time: 15:50)

And here we see the application of a sheet drain or a boat drain, that can be fixed on a retaining wall like this. This soil is compacted behind it and any water that enters the back fill can go through this, the geotextile then come down. And here you see a perforated pipe that is collecting all the water, that comes down these drainage boards and it is safely led away from the structure.

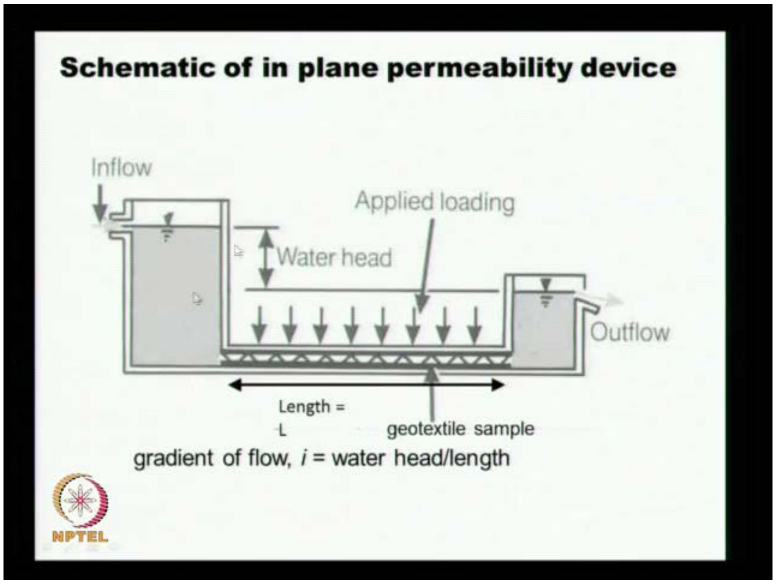
(Refer Slide Time: 16:27)



So, how do we design these drainage medium. See they should have adequate filtration capacity that will prevent the drain from clogging. In the earlier lecture, we have seen some requirements and what is a good filter and how to design it. And similar principles we can use even for designing the filters around a drainage medium. These drainage media should have adequate inflow and outflow capacity and the design loads, to provide for maximum anticipated seepage capacity during the design life.

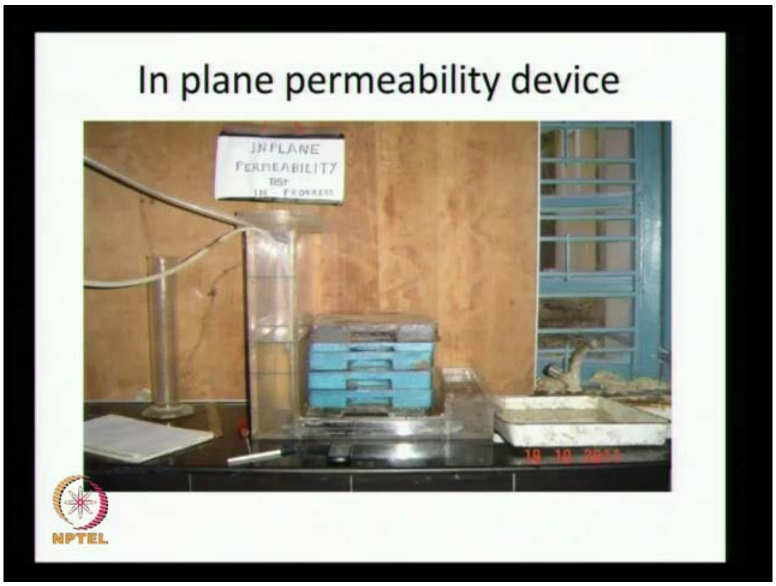
The maximum anticipated seepage capacity is required under the worst possible flood condition or under the worst possible rains, when we have sudden down pours, we should be able to cater to that. This drainage medium it should allow the water to flow in so that we reduce the surface runoff and it should also allow for outflow because this water whatever enters the drainage medium should not remain there. It should be able to flow out of the structure and as a whole, the system could consist of geotextile or perforated pipeline or geotextile covering or inner core of a drainage medium and then stone aggregate. All of these as a system should perform satisfactorily during the design life.

(Refer Slide Time: 18:03)



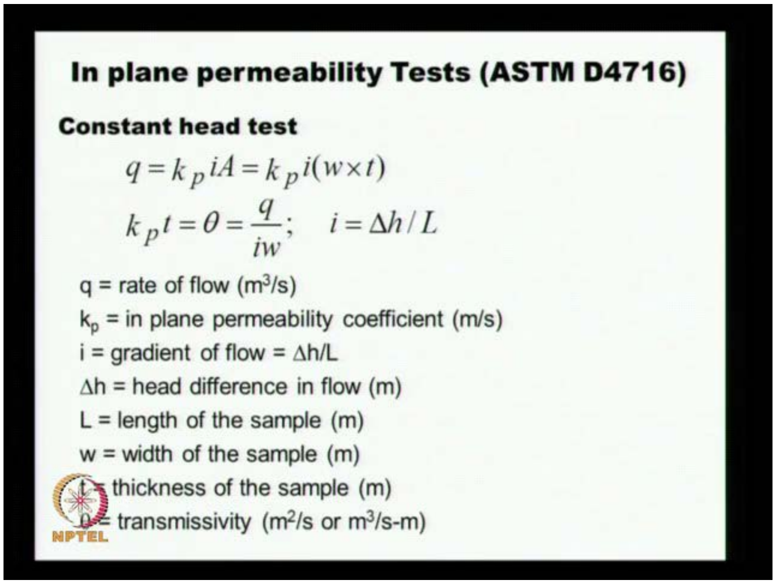
The capacity of our drainage medium is tested in the laboratory using in plane permeability device. In plane permeability device looks something like this. We have two water tanks that can provide some gradient hydraulic gradient. We provide or we place the drainage medium either a geotextile or a geonet here between two rubber sheets as required by the ASTM code. And apply some normal pressure and allow the water to flow through. Then based on the gradient that is there, and the quantity of outflow, we can calculate the drainage capacity or the in plane permeability of the drainage medium.

(Refer Slide Time: 18:53)



Here we see a photograph of the same apparatus. Here we have two water tanks and the geotextiles sample is placed inside. And if we have a small pressure to be applied, we can just simply use dead weights. If we want to apply very large pressure let us say 100 or 200 Kpa, we can have a pneumatic system. And we can place this entire apparatus in a loading device and apply higher pressures.

(Refer Slide Time: 19:31)

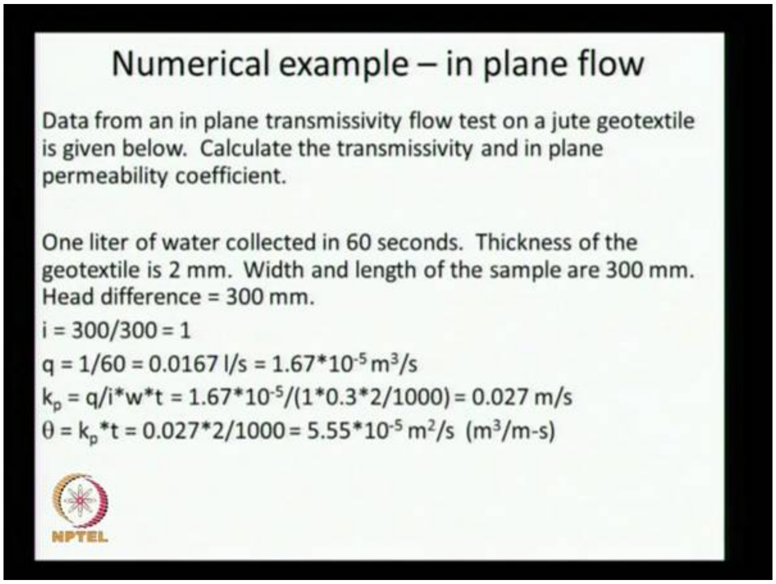


We can collect the water that comes out and we have a standard equation to estimate the flow capacity that is shown here. The ASTM test standard is ASTM D4716 that is to calculate the plane permeability or the permittivity of the geotextile or drainage medium. The q is the flow capacity, the K p that is the permeability tends i is the gradient or the hydraulic gradient multiplied by the flow area a, that is the width of the sample times the thickness and the K p times t is defined as theta.

This theta is the transmitive transmissivity that is the simply q by i w, where i is the hydraulic gradient delta h by l. Here this i is the water head, that is driving the flow divided by the length of the geotextile sample or the geosynthetics sample. The q is the rate of flow, and the K p is in plane permeability coefficient, i is the hydraulic gradient delta h by l, and l is the length of the sample, and w is the width of the sample, and t is the thickness of the sample. And is actually we like to remove this t from the equation for k because the t itself is a function of the pressure.

Most of the thick geotextiles or the geonets, they are subject to some compression. Say if you apply very large pressure, they can compress and that reduces the flow capacity of these geosynthetics. So, whenever we do these tests, our normal pressure that we apply should correspond to the pressure that we expect in the field, because otherwise there is no meaning in these properties. Because at very low pressures, they may have very high transmissivity coefficient, but if you take this, and put it in a wall with that applies very large pressures, this high coefficient may not work.

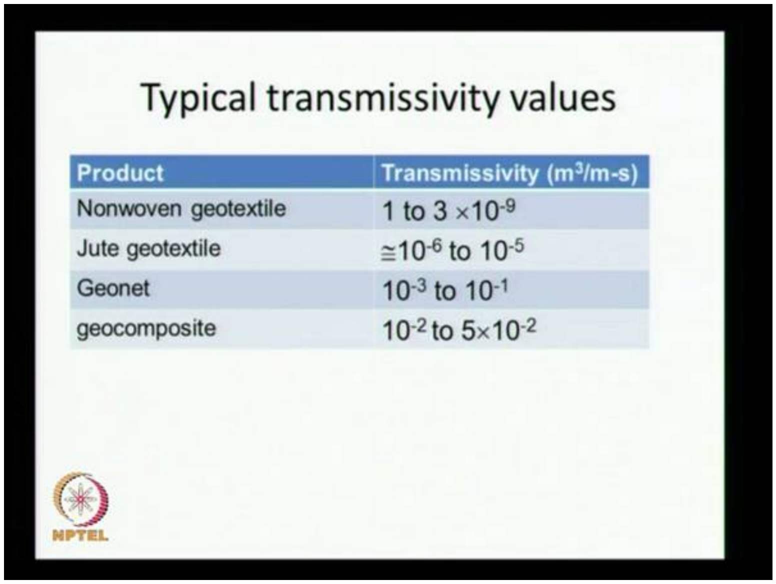
(Refer Slide Time: 21:45)



And there we can have a disaster just waiting to happen. Let us look at a small numerical example on how to calculate the transmissivity. Let us say that we have collected this data say that within about 60 seconds we have collected 1 liter of water. The thickness of the geotextile is 2 millimeters, and the width and the length of the samples are 300 mm and the head difference between the upstream and downstream side is 300 mm. So the hydraulic gradient is just simply 1.

The rate of flow is the water collected per unit time that is 1 liter divided by 60 that is 60 per seconds, because this 1 liter of water was collected 1 minute. So, this q works out 1.67 times 10 to the power of minus 5 cubic meters per second and our K p is 0.027 meters per second. The theta is K p times t that works out to 5.55 times 10 to the power of minus 5 meters per second, or you can also write it as so many cubic meters per meter length of the sample meter length, the outer plane direction where time that is the second.

(Refer Slide Time: 23:13)

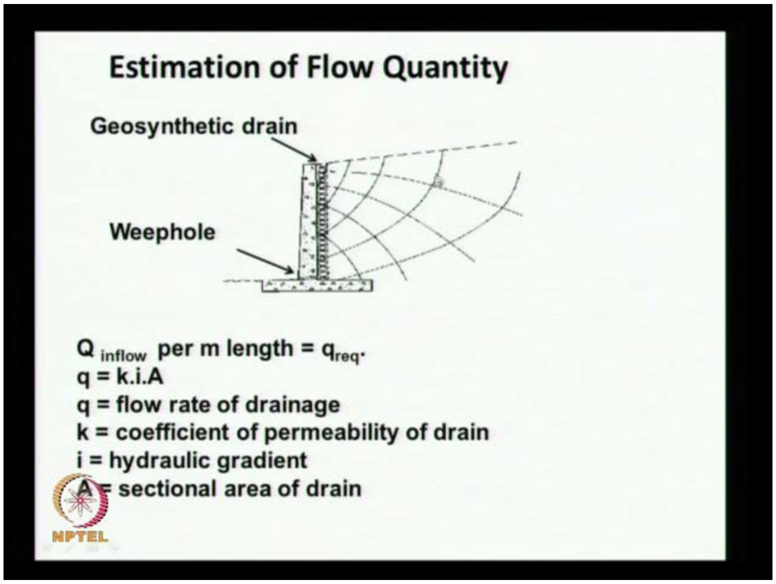

Typical transmissivity values

Product	Transmissivity (m^3/m-s)
Nonwoven geotextile	1 to 3 $\times 10^{-9}$
Jute geotextile	$\cong 10^{-6}$ to 10^{-5}
Geonet	10^{-3} to 10^{-1}
geocomposite	10^{-2} to 5×10^{-2}

And some typical transmissivity values for a nonwoven geotextile, they are anywhere from 1 to 3 times 10 to the power of minus 9. Actually, this is only some average indicative value at a very low normal pressure of 10 K p a, but this all depends on the normal pressure that we apply. And the type of geotextlie that we have, say the thickness and then the pore structure because we have seen that the needle punch the geotextiles are there. And then we have resin bonded and so many different types of nonwoven geotextiles.

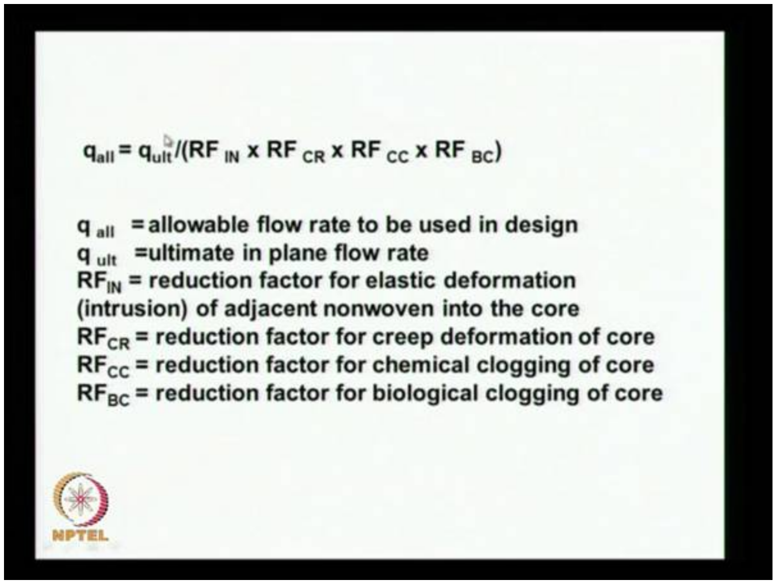
And in comparison the jute geotextiles, they have much more higher open area and they have the transmissivity of about 10 to the power of minus 6 to 10 to the power of minus 5. The geonets, they have much higher transmissivity because they are much thicker 10 to the power of minus 3 to 10 to the power of minus 1. The geocomposite they are like our drainage boards which are much-much thicker even as compared to geonets. They can have very high permeability coefficients. How do we estimate the flow quantity?

(Refer Slide Time: 24:32)



Well, the flow quantity is estimated in the same manner as how we have done it in the geotechnical engineering courses that is by drawing the flow net. Say for example, here we have a retaining wall, and we want to design a drainage medium behind this retaining wall. We need to draw the flow net that is consisting of flow lines and then equipotential lines and then we can estimate our flow into the drainage board. Then the flow through itself is the k times i times a where, k is the transmissivity coefficient, i is the hydraulic head at the hydraulic head, a is the is the area available for the flow. And this these properties they are best determined at the indicative normal pressures.

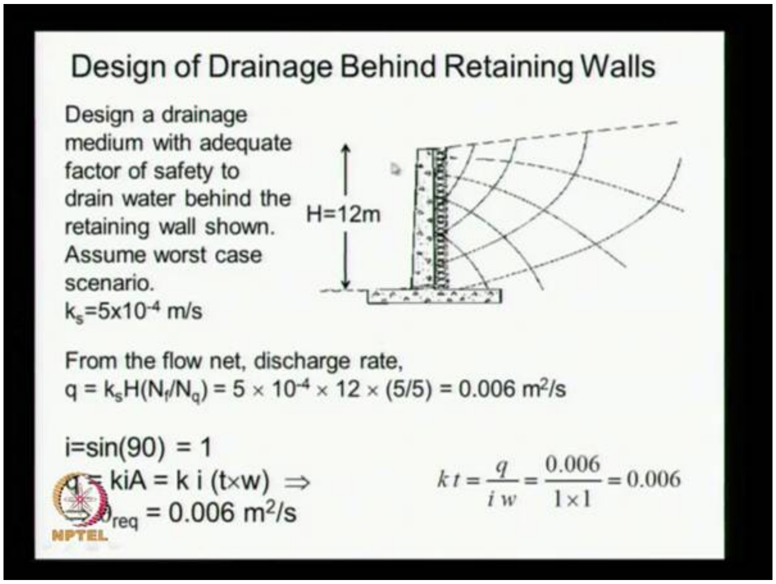
(Refer Slide Time: 25:41)



And the q allowable that we can allow is equal to the q ultimate. The ultimate flow rate divided by number of correction factors these are similar to the factors, that we have applied to calculate the long term design strength of the tensile strength of the geosynthetics. Similarly, the long term flow rate is the short term flow rate or the q ultimate that is determined from laboratory tests divided by so many factors. Here the intrusion damage or the reduction factor for elastic deformations and the CR is the reduction factor.

Because of the creep deformation because all these geosynthetics materials they are made of polymeric materials and if we subject them to constant pressure, they can undergo some creep deformations or the period of their service life. So, we need to also account for the creep the compressions that are induced by the creep deformations. And then R F c c that is the reduction factor because of the chemical clogging. This chemical clogging can happen especially, when we have these drainage medium in the landfills. Then the clogging could also happen because of the biological activity or the microbiological activity. So, all these factors they have to be estimated based on relevant laboratory test to determine the allowable flow rate or through our drainage medium. Now, let us look at some design examples.

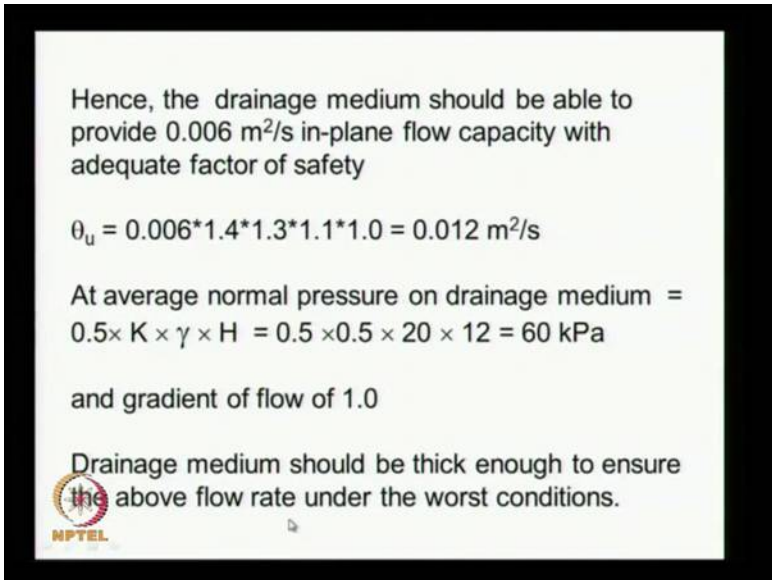
(Refer Slide Time: 27:32)



In particular two design examples, let us first see how to design at a drainage medium behind our retaining walls. Let us take the case of retaining wall which is 12 meters high and the soil has a permeability of 5 times 10 to the power of minus 4 meters per second, which says that its relatively granular soil. The flow net is drawn like this with number of flow streams of 5 and potential drops of 5. So, the flow quantity per unit length in the perpendicular direction is K s that is the permeability coefficient of the soil h.

The height of the retaining wall N f by N q that comes to 0.006 cubic meter per second per meter length. So, it comes to 0.006 meter square per second and the discharge capacity of our drainage medium q is written as k times i times a where, i is the hydraulic gradient. In this case it is just simply the sine 90 because its vertical. So, the height of the water is this much and the length of the drainage spot also this much. So, i becomes just simply 1 and the q is K i A and the area of flow a is the thickness multiplied by the width. So, our theta required is just simply 0.006 because our i is 1 and the width is 1 that is width is in the perpendicular direction to the plane of analysis, so our k times t is 0.006. So, our transmissivity that is the theta required is 0.006 meter square per second.

(Refer Slide Time: 29:37)

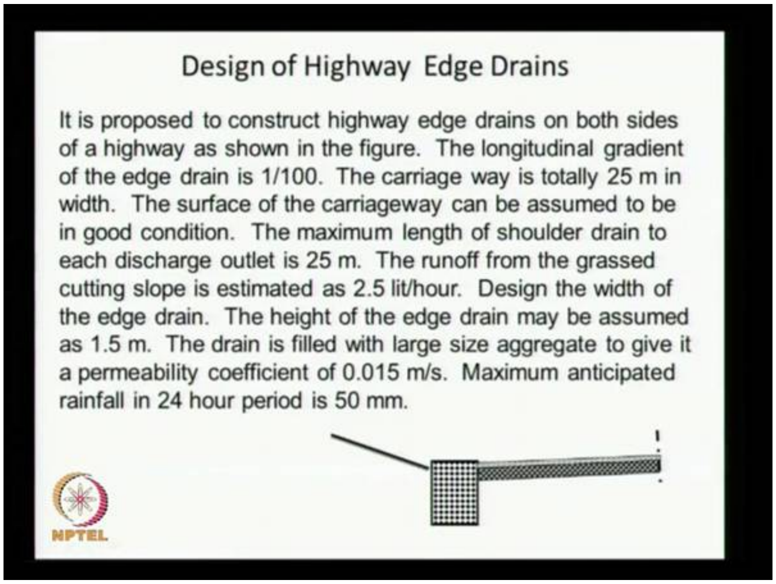


And that is the safe value that we need and the ultimate drainage capacity is obtained by multiplying with different factors of safety 1.4 for insulation damage, 1.3 for deep reduction factors, 1.1 for chemical clogging factors. Then one is assuming that, there will not be any micro biological activity we can take factor of 1. So, our theta ultimate required becomes 0.012 meter square per second per meter length of the wall. And this drainage medium it should be able to operate at this drainage capacity at normal pressure average normal pressure of 0.5 k gamma h.

This normal pressure that we are thinking about is, the pressure that is acting on the drainage medium. So, this is actually the lateral pressure that is acting. The average lateral pressure becomes the normal pressure that is acting on the drainage medium. So, it is 0.5 k gamma h and assuming that k is about 0.5 and gamma is at 20 kilo Newton per cubic meter and height is 12. So, this becomes 60 K p A and the gradient of flow is 1, as we have seen earlier.

So, the drainage medium that we provide, it should be able to have a drainage capacity of at least 0.012 meter square per second at an average normal pressure of 60 K p A and gradient of 1. And we have already seen from experimental data that the drainage capacity is also function of the gradient and of course, the normal pressure. This discharge capacity that we have calculated of 0.012, we can easily select a commercial product either geonet or a geocomposite or a geotextile that is thick enough that can supply this much of drainage capacity. So that is about the design of the drainage medium behind the retaining walls.

(Refer Slide Time: 32:09)

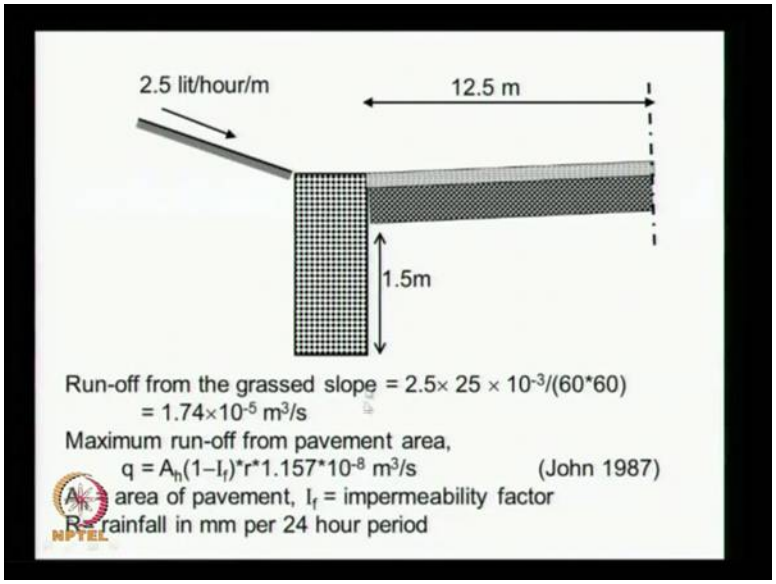


Now, let us look at another example on how to design the highway edge drains. The edge drain something like this which is also called as French drain if it buried in the soil. And we have seen that there are so many variants on this. We can have a geotextile covering or we can have a perforated pipeline and so on. Let us look at the data that is given is proposed to construct a highway edge drains on both sides of a highway as shown below. This is the sketch and the longitudinal gradient of the edge drain is 1 in 100 that is 1 vertical to 100 horizontal distance.

And the carriage weight is totally 25 meters in the total width. And we are only seeing the symmetric top and the surface of the carriage weight can be assumed to be in good condition that means that the ashfault or the concrete pavement that is provided on top is in a good condition. And the maximum length of the shoulder drain to each discharge outlet is 25 meters. The runoff from the grassed cutting slope this is the shoulder area it is estimated as 2.5 liters per hour.

And the design the width of the edge drain, if the height of the edge drain is given as 1.5 meters, this height is given as one point five meters and we need to design this width so that it will have adequate flow capacity. The let us assume that this drain is filled with large size aggregates uniformly sized large scale aggregates to give it a permeability coefficient of 0.015 meters per second. The maximum anticipated drain fall in 24 hour period is given as 50 millimeters. And so we need to first estimate the runoff quantity that enters this drain and then make sure that this drain has so much of discharge capacity.

(Refer Slide Time: 34:19)

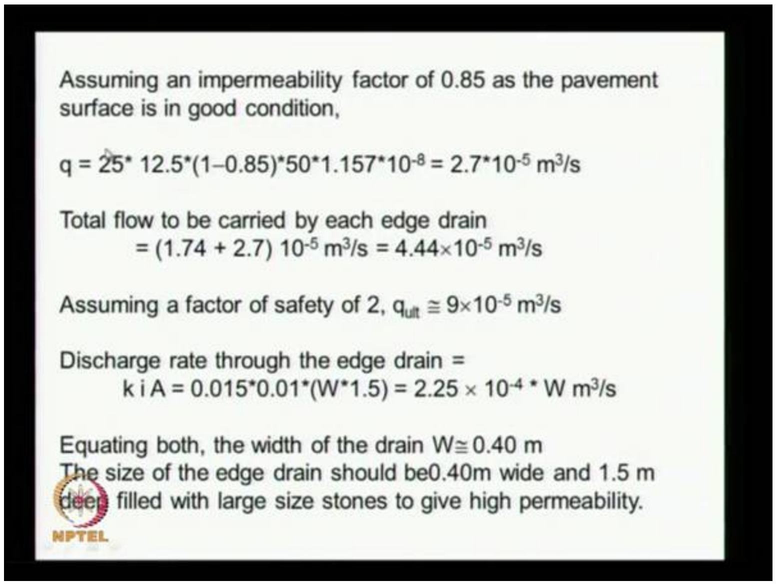


This is our drain that we are going to provide and the surface runoff from the shoulder area is 2.5 liters per hour per meter length, that is per meter length in the plane perpendicular to the plane of analysis. And half width of our highway pavement is 12.5 meters, the total width is 25 meters and our depth of the side drain is given as 1.5 meters. So, the runoff from the grass at a slope is 2.5 liters multiplied by 25 meters that is the intercepted drains are provided every 25 meters.

And so many liters, so in terms of cubic meters 10 to the power of minus 3 and this quantity is in so many liters per hour. So, per second is divided by 3600 so this comes to 1.74 times 10 to the power of minus 5 cubic meters per second. The maximum runoff from the pavement area it is estimated through different empirical equations. This particular formula that we have taken is from the text book by John on geotextiles that was published in 1987.

This is an empirical formula that relates to the catchment area of the pavement, and the condition of the pavement and the rainfall intensity and multiplied by some empirical coefficient like this, the q discharge quantity is equal to A h. That is the area of the pavement that is contributing to the runoff multiplied by 1 minus I f. I f is the impermeability factor, r is the rainfall in millimeters per 24 hour period multiplied by this factor, so many cubic meters per second.

(Refer Slide Time: 36:31)



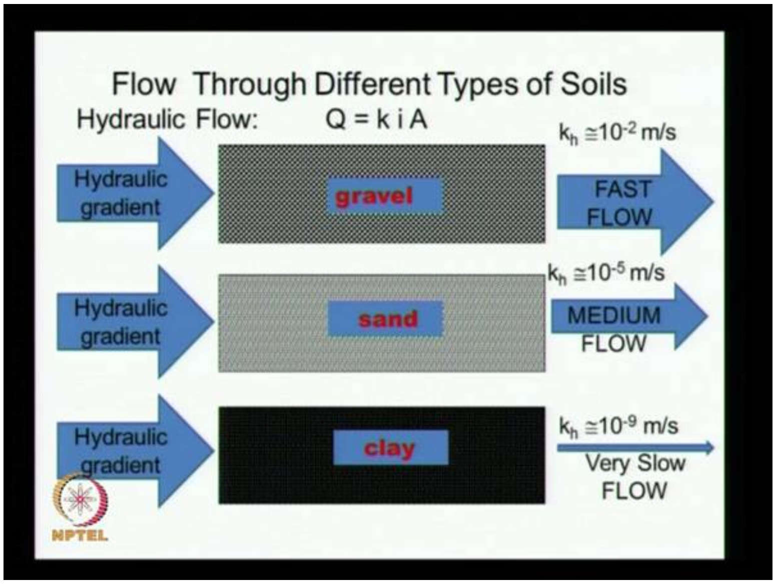
Our pavement is in a good condition so we can assume an impermeability factor of 0.85 corresponding to the good condition of the pavement. Our interceptor drains are provided every 25 meters and the half width of the pavement is 12.5 meters. So, the quantity of runoff that is entering our side drain is 25 times, 12.5 times 1 minus point 85 multiplied by 50 mm per 24 hours multiplied by this empirical factor, that comes to 2.7 times 10 to power of minus 5 cubic meters per second. So, the total flow to be carried by each of the side drains is 1.74 from the grassed area plus 2.7 from the pavement area.

This whole thing multiplied by 10 to power of minus 5 cubic meters per second and this comes to approximately 4.5 times 10 to power of minus 5 cubic meters per second. And applying a factor of safety of two, we can increase the desired discharge capacity to almost 9 times 10 to power of minus 5 cubic meters per second. And this we should equate to the discharge capacity of the side drains to get our dimensions, and the discharge capacity of the side drain is K times i times A.

And the K is given as 0.015, i is the hydraulic gradient that is given as 0.01 and A is the cross sectional area that is available for the flow, that is the width of the drain multiplied by 1.5 meters height this comes to 2.25 times 10 to the power of minus 4 times W cubic meters per second. So, equating this quantity to the q ultimate, we get the width of the drain as approximately 0.04 meters. So, that means that our side drain should be at least 0.4 meters wide and 1.5 meters deep.

And this should be filled with large size stones to give it a high permeability of 0.015 meters per second. If we anticipate lot of sediment transport that is likely to clog the side drain, we could think about covering the entire edge drain with geotextile with suitable geotextile, and that has an apparent opening size consistent with the soil surrounding this drainage medium. And the criteria for selecting the geotextile is as per our earlier discussions. So, we see that the for this particular data that is given, if we provide an edge drain that is 0.5 meters wide and 1.5 meters deep, it will be able to carry the runoff that comes not only from the grassed area, and also from the pavement area.

(Refer Slide Time: 39:58)



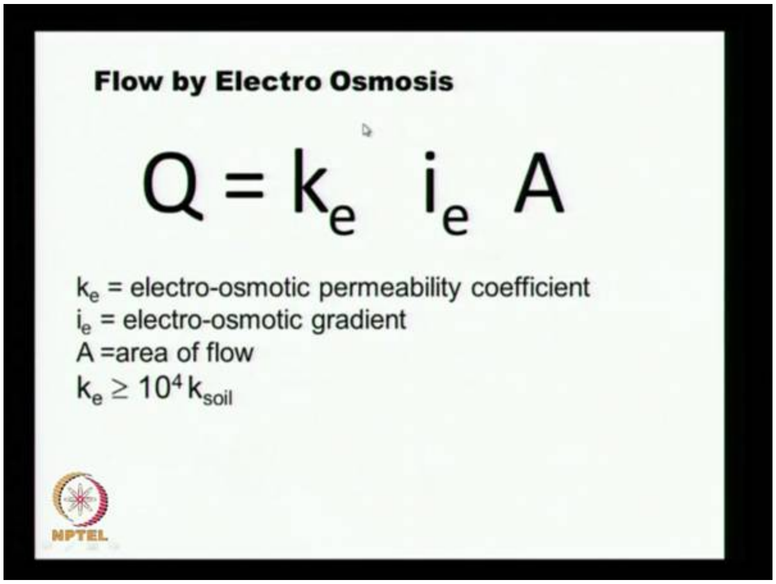
So, far we have seen the what is geosynthetic drainage medium and then how to design the drain capacity and so on. Let us digress a little bit and let us look at the capacity of different type of soils to allow for flow of water. Let us say that we have three different soil mediums. One is gravel that is consisting of very large particles, the other is sand that is consisting of smaller size particles, and the other is clay which is really-really consisting of small size particles.

Let us say that we subject these three mediums to the same hydraulic gradients. And let us say that the cross sectional area of the flow is the same in all the three mediums. And in the gravel because the flow capacity is very high, the flow is very fast, the flow coming through the gravel is very fast because our the permeability coefficient is very-very high of the order of 0.01 meter per second and with sand its slightly lower, even if it is subjected to the same hydraulic gradient.

And similar cross sectional area is available because the permeability rate could be much-much lower. Actually, this is more applicable for silky sands may be mixed with some clay particles. And we can say that, we have medium flow or the discharge capacity is not bad, but when it comes to clay salts it is really-really slow, because our permeability constant is very small of the order of 10 to the power of minus 9 meters per second. Depending on how well the clay soil is compacted.

And what do we do if we want a faster flow through this type of soil mediums. So, with gravel and the sand, we have no problem because the permeability rate is so high that the water can easily flow, but when it comes to clay soils the water is very-very slow in travelling. So, if depending on the drainage path length that, we have it takes very-very long time. And this we see in the consolidation. The consolidation is a very long time process it takes years together for the soil to be consolidated.

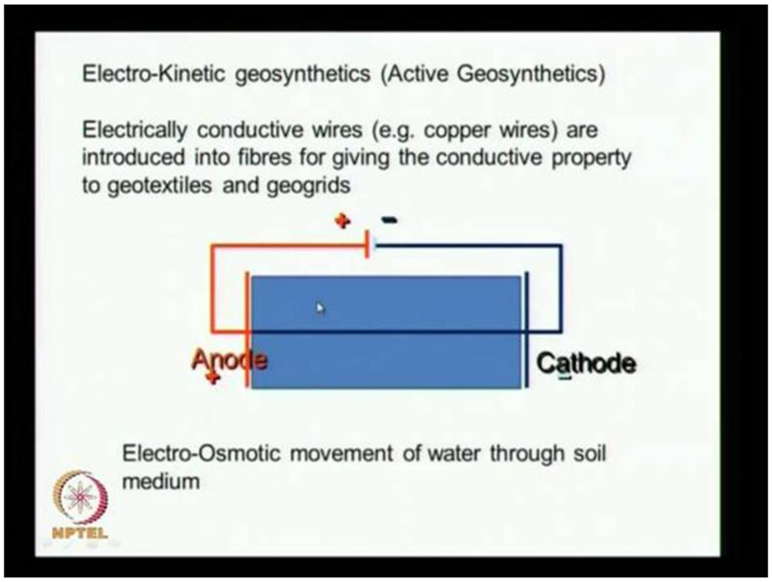
(Refer Slide Time: 42:33)



So, in that case we can go for Electro Osmosis. So, this is a standard technique that we use in all our geotechnical engineering. Whenever we are treating a extremely soft clay soils, which have very low flow capacities, we can apply some electrical potential difference and drive the flow and electro osmosis flow is shown like this. The Q is K e times i e times A, where K e is the electro osmotic induced the permeability coefficient, which could be very much different from what we have under normal water flow, i e is the electro osmotic gradient. And here this K e and i e they are controlled parameters.

Depending on the gradient of the current that we apply we can increase the K e and also i e and these two parameters that we can easily control. Whereas, in the previous case the K h is natural property of the soil that we have no control, that is because of the natural formation of the soil. And the gradient of the flow also we cannot control very much because we already have the soil at the side and the water conditions, we know and that much is the gradient that is available for the flow. But here in this electro osmosis, we can by changing the potential that we apply, we can change not only the gradient, but also the permeability.

(Refer Slide Time: 44:12)

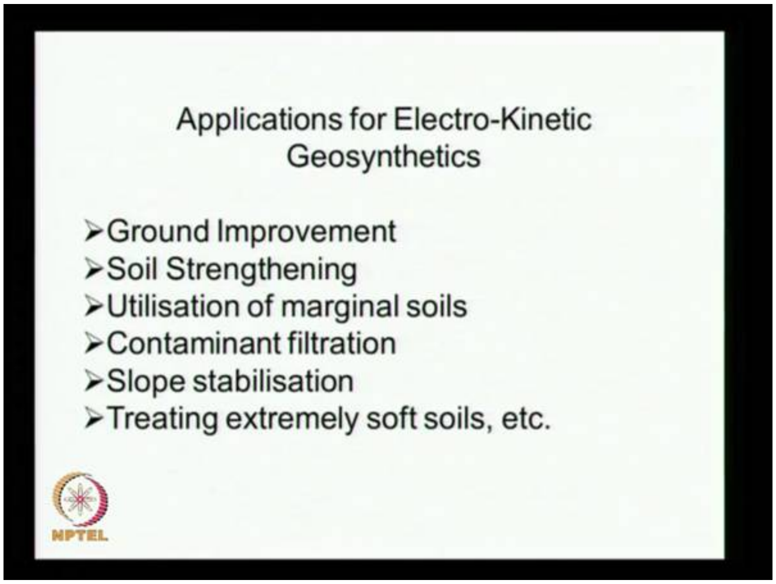


So, here the application is given like this and we have a new type of geosynthetics which are called as electro-kinetic geosynthetics. In some literature they are also called as active geosynthetics because they are doing some work. They are just not simply supporting the load passively, but they are actively doing some work by passing by passing current and by treating the soil. And similar to the woven fabrics and other fabrics we have electrically conducting geosynthetics.

What we do is we put in some highly conductive wires thin wires example copper wires into the fibres while weaving the fabrics. And that gives them a good conductive properties to the geotextiles and geogrids and we can apply some potential difference between the two ends anode and cathode and drive our water flow.

So, this is an example of how we can apply and the same thing we have been doing in this all structures, but now we have these electro kinetic geosynthetics in the form of geotextiles and geogrids. And these have been applied successfully in treating the embankments or retaining walls. There are some test walls, which were built with soft clay soils as back fills by providing electro kinetic geosynthetics they were able to stabilize the soil in a very short time.

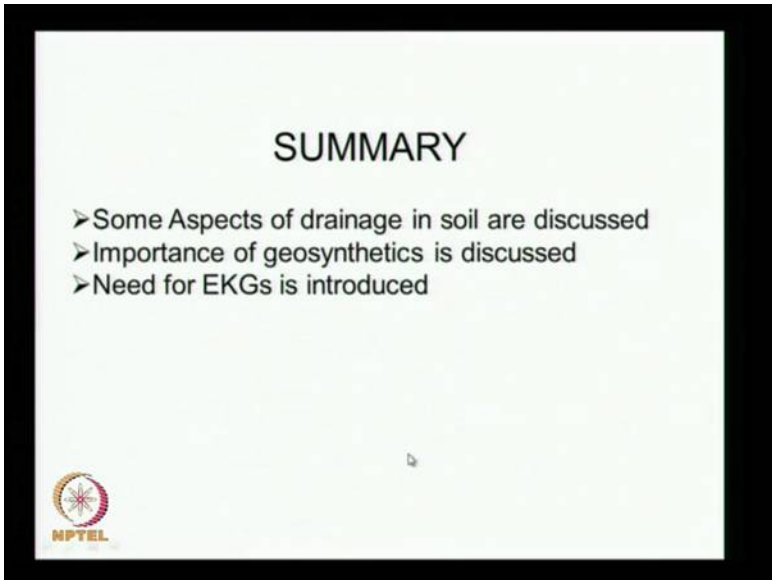
(Refer Slide Time: 46:01)



So, some of the applications for the electro-kinetic geosynthetics are obviously in the ground improvement works. The soil strengthening just by passing the current by polarizing the soil particles, we can increase the strength in order of magnitude and the utilization of the marginal soils that is once again because we are able to improve the strength of the soil in a short time, we can utilize the marginal soils. And then contaminant filtration this is one very important factor that we have in our landfill or other environmental applications.

We can promote the faster segregation of the waste or for the decanting purposes. If we provide these electro kinetic geosynthetics, we can have we can collect all the suspended particles much faster. And so that we can lead all the reasonably clear water out of the landfill or out of our pond. We can use these electro kinetic geosynthetics for slope stabilization for treating extremely soft clays.

(Refer Slide Time: 47:18)



So, this these electro-kinetic geosynthetics, they are not freely available in the market, but there are some specialized companies that are fabricating that are manufacturing this type of geosynthetics. And may be in future they will be as common as our normal geogrids and geotextiles. So, just summarize we have seen the some aspects of drainage, we have seen what is drainage. And then why it is important to provide for drainage our soil structures. We have seen how the geosynthetics can be used as drainage medium in the soils. The need for the EKGs that is the electro-kinetic geosynthetics is briefly introduced. So, this is a brief summary of the drainage aspects. How we can use the geosynthetics for drainage purposes.

So, thank you very much.