Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites

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Lecture - 11
Liners for Landfills - Part 2

A good day to all of you and we will continue our discussions on liners for landfills. We started this discussion last time we looked at the concept of composite liners. And we also said that we are not aware of any single material which can meet all our requirements of a impervious base of a solid waste disposal facility.

So, let us have a quick recap of what we did last time and then we will take it on from there.

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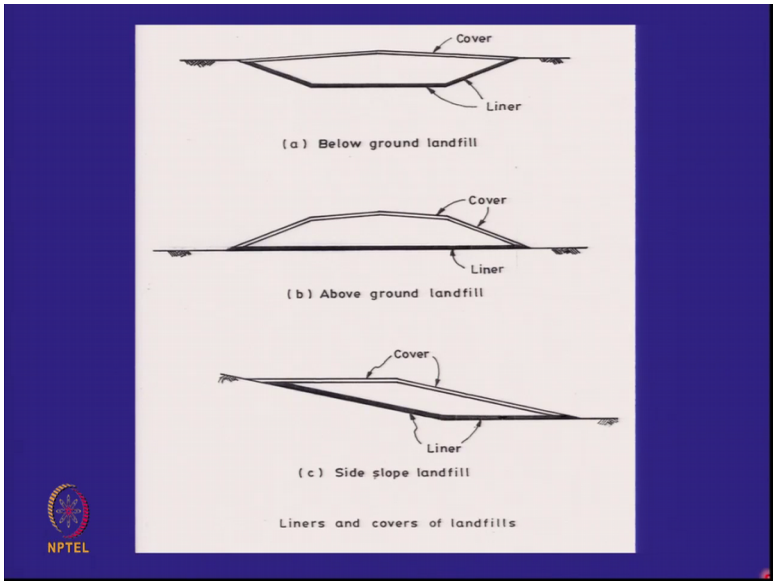

Just to remind that the liner is at the bottom. If you have a below ground line fill the liner is the main component cover is less if you have an above ground landfill liner is less cover is more.

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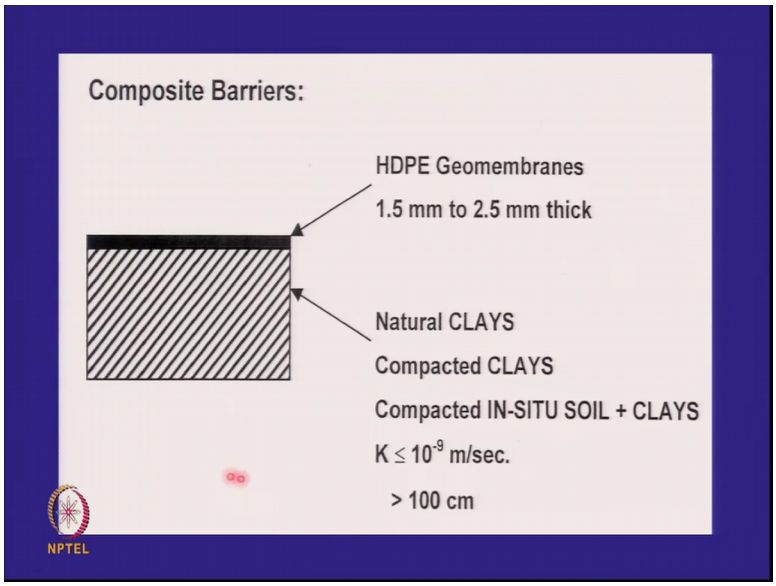

And on a side slope landfill these may be of similar order. And after our discussion on various materials we said this is what we nowadays accept as an acceptable hydraulic barrier. A geomembrane thick geomembrane and an in low permeability soil it can be natural clays in that area it can be clay imported from an outside area and compacted or if you have in soil to which you can add commercial clay any of these if it gives less than 10 to the power of minus 9 meters per second as the permeability and it must be thick.

So, this is anything which is thin is can be punctured can be torn can crack you say I do not know I will use a clay which is 10 to the power of minus 10, but I will use it one 10th of this 10 centimeter thick clay; that means, I will have this much clay fine you do have this much clay.

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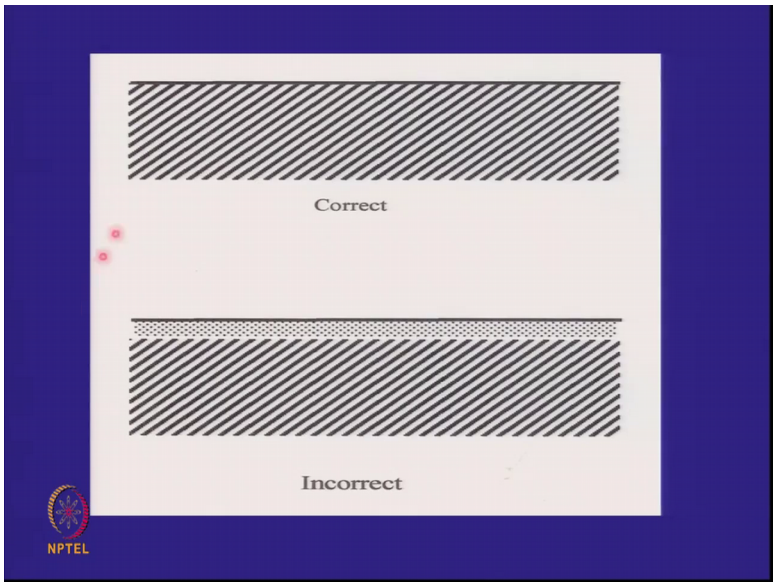

But when it settles is it going to crack is it going to get a preferential pathway. So, you need a thick a 1 meter, a 1 meter, a 2 meter.

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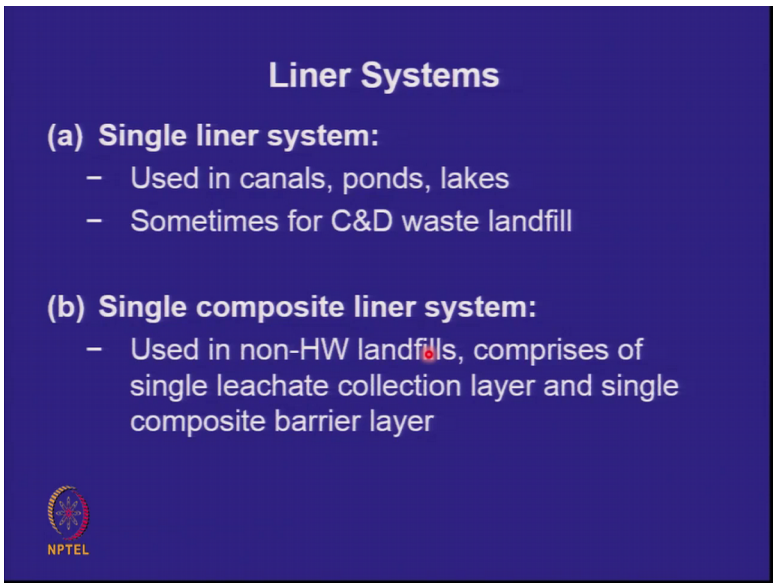

So, you need thick and a thin impervious thin on the top and we said intimate contact is essential. If you do this the composite barrier does not work. And we talked about single liner systems only one element not used for landfills. Except sometimes for C and D waste, because C and D waste are often termed as inert, but they are used in canals ponds

and lakes single composite liner system the one which we have seen just now is used in municipal solid waste landfills.

And I just want you to understand the word liner system and the word barrier that I use. Typically, what is that the base is called a liner system? So, it will comprise of the leachate collection system also as well as the barrier system. So, it is the whole thing put together in some books they will only talk about the barrier system as the liner system. So, it is a terminology which is not a rigidly fixed. When I use the word liner system I normally include the leachate collection and the barrier at the bottom. So, I am talking of a single composite liner system it will have a composite barrier layer.

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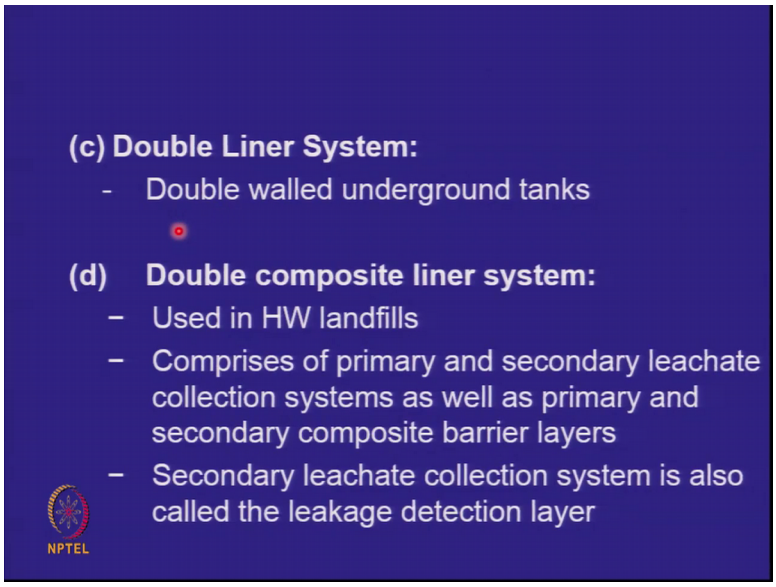

Double liner system is distinct from double composite liner system. And double a double liner system you put an underground petrol tank and the regulatory authority says I want to know if it leaks. So, I said I will put a double walled tank inside steel outside steel or inside polymer outside polymer, and when it leaks I will get liquid in the airspace between the 2, I can tell you that it is leaking. Not acceptable for landfills only a double composite liner system is acceptable for landfills, because you can take out an underground drum and you can repair it, but you cannot take out a liner of a huge landfill which has been covered with a lot of waste.

So, the double composite liner system has a primary composite liner system and a secondary a composite liner system. So, it will have 2 elements, a leachate collection

layer and a primary barrier then another layer where the liquid can travel and a barrier. So, the secondary system is called the secondary leachate collection system it is also called the leak detection layer. Just like I gave you the example that you have a double walled drum, then the outer wall serves to tell you whether leakage has occurred or not. Similarly, in a double composite liner system you will have a leachate collection layer at the top which will take away most of the leachate, if something comes through this it will come beneath it the moment it comes beneath the clay of the primary barrier that is leakage.

So, you need another sand layer or another drainage layer which can detect that leakage. So, that is called the secondary leachate collection system; that means, whatever comes through you will take it out, but it also is called a leak detection layer.

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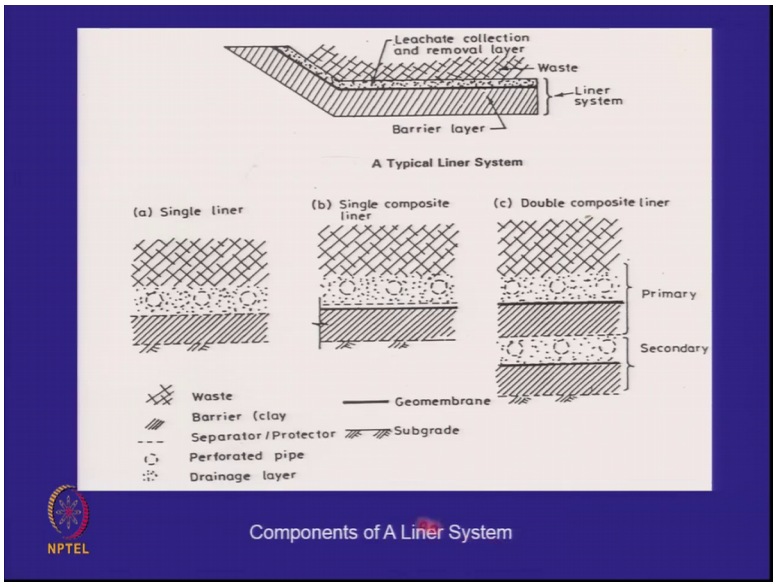

And we talked about this last time waste here a drainage layer. So, it is I have depicted it with sand and gravel with some pipes inside it. This is the leachate collection system this we will look at later. We are at the moment talking about the barrier layer this is a single liner with a single barrier. If you just go from here to here, you now get a dark line. So, that is a composite barrier, geomembrane plus clay thin plus thick there is another dotted line here we will come to that a little later.

It may or may not exist. And if I just go from here to here I have 2 of these composites, 1 and 2 this is the primary system this whole leachate plus barrier and this is the secondary

system. And this layer is often also called the leak detection layer. What is the difference between the top one and the bottom one this can handle more liquids? This will handle less liquids because leakage is going to be very small any confusion on this.

No remember for a system to be a double system you have to have an air gap or you have to have a drainage layer between the 2 sticking, 2 things together does not make a double otherwise then you will say sir this is a double system. This looks like a double system one liner and another is not that right, but this is not a double liner this is a single composite liner. If there is an air gap between the 2, then it becomes a double liner system, but not a double composite liner system.

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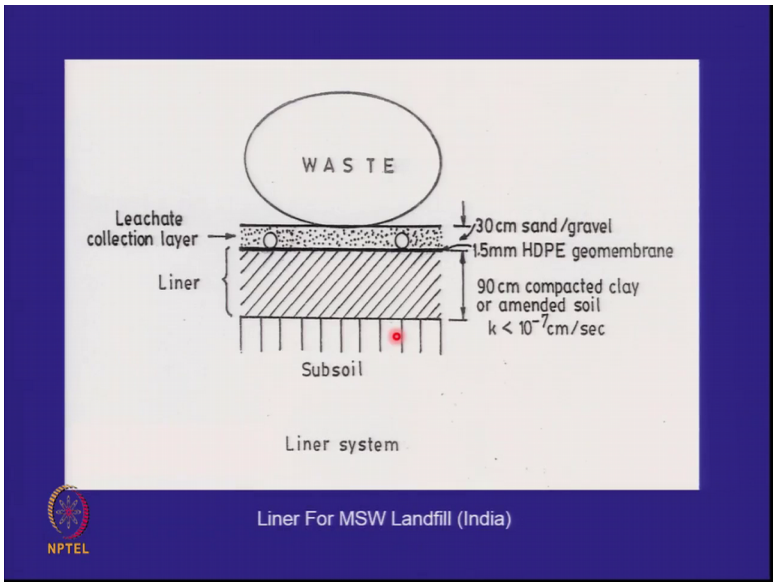

So this is used normally for C and D you may have clay or somebody may choose to have a geomembrane alone. This is used for municipal and this is used this is also sometimes used for hazardous waste, but the thickness of the clay is very large and this is used for hazardous. So, if I look at the specifications in the Indian environment that is the central pollution control board and the ministry of environment and forests, this is a waste it says that the leachate collection layer should be a 30 centimeter thick sand gravel layer that is it a sand gravel high permeability layer. And the base of the landfill should always be tilted to one corner. So, that all of it can flow to a some like a bathroom drain and there it can be collected.

In this they are perforated pipes sometimes you may need them sometimes you may not need them, but the idea is they should be able to carry whatever leachate comes and allow a easy passage beneath that is a 1.5 mm HDPE geomembrane. So, now, there are these issues about what is HDPE why not PVC why not PET, PVC is polyvinyl chloride HDPE is high density polyethylene PET is polyester. So, there are different kinds of polymers that we have, but at the moment for this course, you will have to accept that HDPE is the most chemically resistant polymer and then I have the subsoil.

So, this is for municipal solid waste. So, prescribed by the central pollution control board or the ministry of environment in the hazardous waste management rules.

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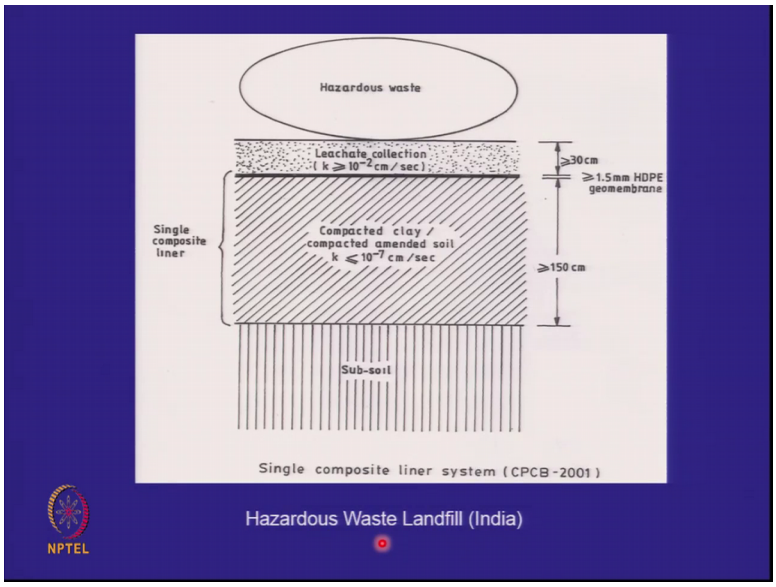

For the hazards; sorry, for the municipal solid waste management rules did I say hazardous waste the municipal soil? If I have hazardous waste I will have 2 I will have 2 a systems. It looks like this and it looks like this. So, I will come back to what is what, but this is a sung single composite liner. In the single composite liner, we are back to this 30 centimeters at the top this is a universal thing of sand and gravel here you can see a permeability value written for you greater than 10 to the power of minus 2 centimeters per second is it visible generally visible maybe the ship in future you should come up a little closer. If you if you are not being able to see from there and I would not pass an electrical current from here I can assure him of that right.

What is the differences, that suddenly this has become bigger? So, this is more than 1.5 meters thick. So, this this is derived from the European practice, and this is for hazardous waste and in Europe, this can be even bigger. And once you have only a single composite liner there are stringent requirements of the subsoil. In the sense they say that you can put your landfill on a subsoil which will have a permeability less than x y z right. So, they wanted you may not should on clay, but they will give you a then you can use a thick clay and this is a single liner system.

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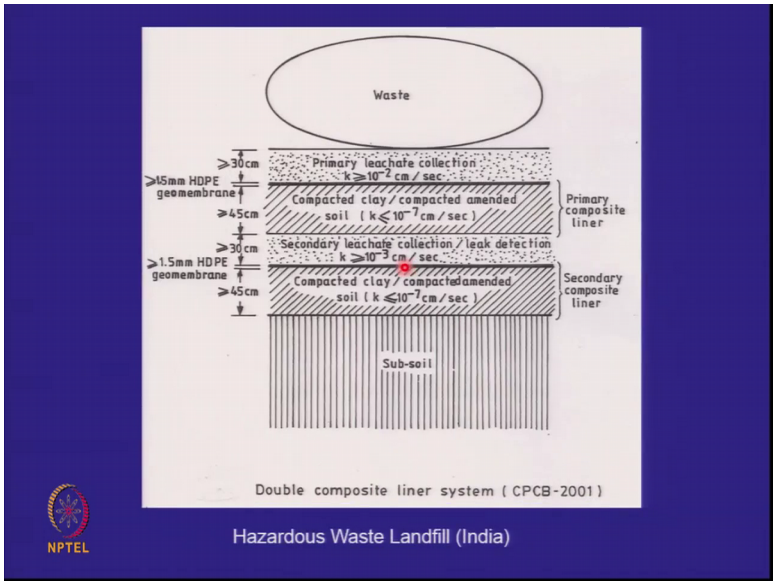

Let me come to the next one, repeat this is a single composite liner for a hazardous waste landfill. And this is a double composite liner waste, 30 centimeters primary leachate collection system 10 to the power of minus 2 greater than 10 to the power of minus 2 centimeters per second. Clay compact, clay greater than 45, I prefer greater than sixty and I will come to that later you can tag this point. I prefer 90. Then a secondary leachate collection system again 30 centimeters, but what has happened to the k here the k acceptable was 10 to the power of minus 2, it had to be greater than that here it is 10 to the power of minus 3.

So, this may be a gravel sand mix this may be a core sand you can have a soil with not as high a permeability. It is not going to handle that much leachate bulk of it is going to be collected here and then again another come composite liner any questions purely from constructability point of view this 45 centimeter should be larger, but this is the

minimum specification this is not a design specification means, whatever your design you cannot be less than this for a geomembrane it can be 2 millimeters. It can be 2.5, but it cannot be less than 1.5 and most of these things come from construction rather than from design issues because nothing should tear or puncture during construction. So, 1.5 mm may be the minimum required for HDPE.

So, when do you have a double liner system for hazardous waste and when do you have single liner system for hazardous waste. Well when the risk is clearly higher, when the risk is clearly higher, you go for double.

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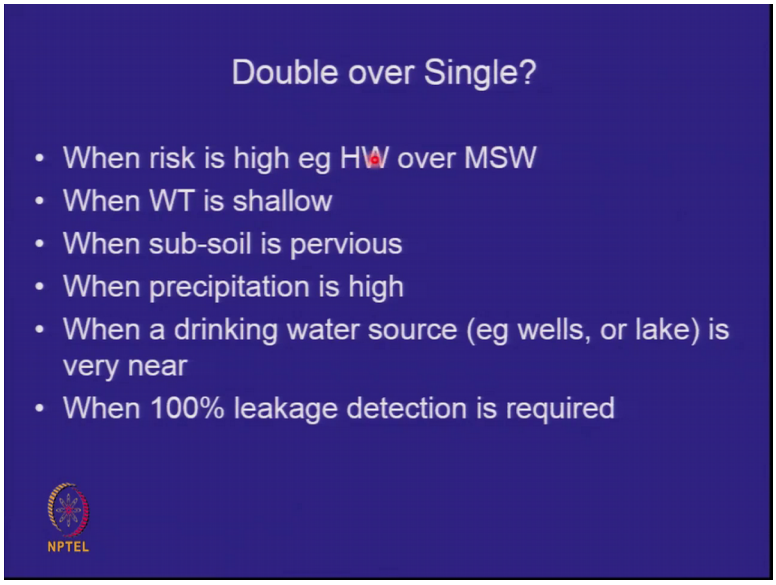

Well when you have hazardous waste you would tend to go for double or single, but when you have municipal solid waste which is non hazardous you go for single it is rare to have a double liner for a non hazardous waste. When is the risk higher when the water table is shallow it is closer to the base. So, you have a hazardous waste shallow water table subsoil is pervious you are sitting on sand and precipitation is high it is raining all the time more leachate.

So, this in fact predetermines when you will use a double system. So, you know and when a drinking water source is nearby a very near, I mean your landfill is sitting next to a bunch of tube wells or pumps which people are using for drinking water then you want to know when your landfill is leaking and whether it needs to be remedial action. So, when you have wells or a lake does not get washed every year un unlike the river where

in the monsoons you will have high flows. So, this is all high risk. So, you will go for a double and some regulatory authorities require 100 percent leakage detection.

So, how do you detect a leakage beneath a single composite liner? I can detect leakage if this is the base and my landfill is above the ground not only is it above the ground it is clearly 3 meters above the ground. I can detect this visually I can walk every day and I can detect it, but if I put a sensor here and say I will put a moisture sensor here, can I detect leakage if I put a sensor here let us say that the round thing is a sensor will it detect leakage yes or no.

Student: No.

Because the water content will go up so, but my problem is a single sensor would not detect it leakage will be taking place there. So, how do you detect leakage. So, I will put a sensor at every one foot still I may not detect it. How many sensors will I put if I am putting it at every a 30 centimeters or a meter I will put hundreds of sensors. So, then I need to need a continuum what do I say I will put another layer underneath it so that when the drop falls on it I can detect it and it will detect because it is slightly sloping it will come to one side.

So, a double composite liner system is. In fact, 100 percent leakage detection system we can make sporadic locations of moisture detectors underneath a landfill base in soil, but it cannot detect if the pathway is somewhere else. So, if your regulatory authority says no in America they say what is the difference between European practice and American practice in America, they say I want to know when it leaks.

So, if all hazardous waste landfills you will have a double composite liner in Europe they say you must have a very thick low permeability soil beneath the clay. So, they are all forcing you to select a particular type of site are you getting you cannot go and put it in your landfill at every location and they will say the water table has to be. So, much deep in India where do we find low permeability soils on the ground and where do we find high permeability soils on the ground. If you look at the top on the map of India are you aware of the soils of India great. So, which part of the country has got low permeability soil?

Student: (Refer Time: 16:43) Himalaya (Refer Time: 16:45).

Himalayas are all rock somebody sided in the Himalayan range. I think all Himalayan slopes have exposed rock or a little bit of soil at the top which is weathered soil, where do we get a lot of clay.

Student: (Refer Time: 17:05) Maharashtra Gujarat.

Maharashtra Gujarat anybody else: maharashtra and Gujarat what is peculiar to Maharashtra and Gujarat that they will have.

Student: (Refer Time: 17:13) coastal regions.

Coastal regions will have. So, you mean in the sea or just before the sea or where this a between high tide and low tide. Do you think you can put a landfill between high tide and low tide right? So, I am surprised that you cannot answer this wherever there is black cotton soil.

Student: (Refer Time: 17:39).

Wherever there is black cotton soil and there are a lot of black cotton soil in India. You are aware of the word black cotton soil.

Student: Yes.

Swelling clays.

Student: (Refer Time: 17:55).

So, all I am saying is a huge amount of area below the central part or within the central and below the central part of India including the Deccan plateau has a lot of black cotton soil or has a lot of clay. The coastal regions have a lot of clay because the rivers have bought the fines and the deposited it there you will get marine clay at various locations. So, you do not have to go into the ocean even several kilometers before that you will find Bombay clay, Bombay marine clay, Calcutta marine clay, will have and which part of a the map do you see in the high permeability soils.

Student: (Refer Time: 18:37) desert.

Desert: so in desert luckily rainfall is low. So, precipitation will be low. So, leachate will be low because it is a desert. So, but yes I mean one place is the desert you will have

doom sets right. The high permeability any other place where you will have high permeability, what are high permeability soils. Clays and silts and clays silts and silty clays are low permeability sands and gravel and sandy silts are.

Student: (Refer Time: 19:12).

So, where are the sandy silts?

Student: Sir, riverbeds.

So, but we are not going to put a landfill in the riverbed, again just remember we have something called the indo gangetic plain the whole plain is alluvial including Delhi, where you are setting and what are alluvial deposit is in the northern north India, in Delhi in mirrored in wherever the indo in Agra what are the what are their soil type.

Student: (Refer Time: 19:44).

Well, if it is sandy silt by joe it is permeable. So, remember the whole of the indo gangetic plain in the north of India is on pervious bed. May not be very pure clean sand, but if you have seen Yamuna sand of that is pure clean sand, but even if it has some silt it is not a low permeability material. So, that gives you the answer as to where you are going to get double composite liners and single composite liners for hazardous waste facilities.

Another important issue is I have shown these diagrams and these do not have all the elements these are the minimum requirements. Let me take an example. Let me look at this interface between the geomembrane and the coarse grained soil on top right. What will be this coarse grained material as I said it will be sand or gravel? So, where will you get the sand and gravel from in Delhi where will you get the sand and gravel from.

Student: (Refer Time: 20:51).

Yamuna gives you coarse sand. If you have done the laboratory course you would have dealt with Yamuna and if you have dealt with Yamuna, please tell me what type of sand is it.

Student: Fine sand.

Well, it is medium to fine sand. So, that is not going to work. So, you need to get coarse sand or gravel and if you get quarried sand or if you get quarried gravel. Then you will have angular particles which can damage this geomembrane, why you are going to put 30 meters of waste on top of this eventually it will start to puncture indent into the.

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So, you need you might need to put another layer here to protect this geomembrane from puncturing. So, I am saying all layers are not shown here and you may need a filter you may need a separator and you may need a protector. And I would like to tell you that each interface which has been put in the minimum guidelines by the ministry of environment and forests and the central pollution control board requires that it be examined for does it need a filter does it need a separator and does it need a protector. So, what in your opinion is a filter? So, what do you what do you mean by the word filter.

Student: allows the (Refer Time: 22:19).

Pardon.

Student: Part of a water.

What allows the passage of water is a filter. So, everything is a filter sand is a filter gravel is a filter cobbles are a filter and what is the other component for it to be.

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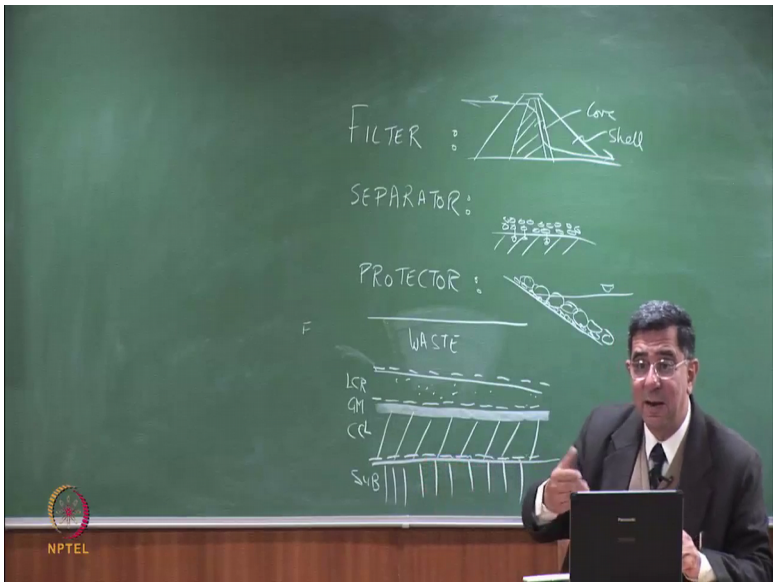

Student: (Refer Time: 22:23) particle.

So, if you allow passage of water without allowing passage of soil that is a filter.

So, it must be pervious it must be pervious enough to allow passage of water, but it should not be. So, pervious than the fines are also washed away with the water and you get muddy water through the soil. So, that is a filter what is a separator where is a filter used in in normally in geotechnical applications, where is a filter used very commonly.

Student: Dam (Refer Time: 23:21).

Where in a dam yes between what and what.

Student: at the (Refer Time: 23:26) toe of a dam (Refer Time: 23:27).

At the toe of the dam I am not sure I have seen a filter at the toe of all dams, but yes it is sometimes used, but is there any other location. What is it doing at the toe what is a filter doing at the toe of a dam.

Student: if the way we particles beneath with dam (Refer Time: 23:48) particles beneath with dam through (Refer Time: 23:50).

So, now you are talking of beneath the dam know that is even more complicated. Flow of soil partings from beneath the dam are you talking of a barrage which was the concrete flow or are you talking of a dam.

Student: Barrage.

Suddenly you have changed that the I said where do you want a filter you said at the toe of a dam now you are saying no a barrage are you still firm with your toe of a dam.

Student: (Refer Time: 24:21) yes sir used on (Refer Time: 24:24).

It is used in both toe of a dam as well as the barrage. So, are you talking of a rock toe at the toe of a dam. Because I think I know of a rock toe at the toe of a dam maybe. So, in any case what we are saying is, when we put coarse grained material in contact with fine grained material we do not want the fine particles to move away.

So, in all dams between the core of the dam and the shell of the dam we have what is called a transition filter. And the idea of a transition filter is that the fine particles of the core should not travel into the shell. That is a clay core, shell and we have been designing transition filters is that when this water flows through this core. None of the fines get washed out at this interface and that is called a transition filter.

At the downstream of a barrage is an inverted filter. And what is the purpose of the inverted filter it is similar water is coming vertically upwards because the barrage floor is impervious if you have it will come vertically upward the fines will want to get washed out. So, on that I put a filters so that I cannot have the fines washing out. So, here also we have to do that check what is a separator. A separator is something which keeps 2 soils separated and does not allow them to mix a separator is one which keeps 2 layers separated and does not allow them to mix a very nice, example of this is when you put ballast of train tracks on soil what happens and where is there a problem and you have this natural ground and you are putting ballast size you know is coarse grained gravel and more.

So, what happens if you have for example, let your soil be soft clay and you put this ballast on top and then you put your tracks. What is going to happen with time?

Student: (Refer Time: 26:57).

The ballast will tend to penetrate into the soil. So, if you want to keep 2 materials totally separated that is your soft clay and that is your ballast just an exaggerated view. So, I do not want these particles you know over period of time due to the trains passing on the top mixing with the clay, because then the effective thickness of the ballast will go down or separator is an element which keeps the 2 separated. And what is the protector.

So, I just now told you a protector is a layer which prevents damage to the underlying layer. A protector is a layer which prevents damage to the underlying layer, an example of protection. A riprap against wave action, your reservoir you understand what is reprap you would you have a reservoir or a lake embankment and your water and under high winds this water will lap against the soil. So, it will try and damage the soil. So, how do you protect the soil from being eroded by the wave action by putting?

Student: (Refer Time: 28:41).

Large size material which will absorb the energy of the waves; so you put what you call the riprap or pitching stone pitching hand placed pitching still it will take away the fines because there are large gaps between the cobbles and the soil. So, what do you need in between?

Student: (Refer Time: 29:08).

Something which prevents the fines from coming out a filter; so you are stone pitching will sit on a gravel pack or on a sand gravel filter. So, you will have smaller so that the fines cannot wash out. So, inevitably we are talking of something protecting the underlying layer.

So, let us look at our now you have got. So, many layers many interfaces between the layers. Filter allows water to pass without fines of soils separator does not allow particles of one soil to mix another soil across and boundary of an interface. Protector prevents puncture or tear or damage of the underlying material the protector is a sacrificial layer; it is not doing any design it is just a sacrificial layer agreed.

Student: Yes.

So, where do you think you need these in our liner? Let me now come to our diagram we have waste. A waste is not like an egg it is just a representation unless tomorrow you say sir waste is like an egg it is not waste is also horizontal.

So, let me make it correctly, I do not want you to waste is also horizontal layer underneath the waste what do I have I have the leachate collection layer. And then beneath the leachate collection layer I have a geomembrane as I shown you sand gravel and then beneath, that I have the clay and beneath that I have the local soil. Visible to all of all of you is this visible waste leachate collection layer geomembrane clay, way I have to look at each interface. And I have to tell you I have to see whether I need a separator do I need a filter do I need a protector.

So, should we start bottom upwards well it is all bottom upwards, it is simpler. It is simpler, that is local soil what we call subgrade that is compacted clay liner this is geo membrane. This is leachate collection layer or leachate collection and removal layer and that is the way. So, many interfaces 1 2 3 are the 3 interfaces forget about the top 1 2 3, but always look at the interface from below and always look at the interface from the top. So, you have 2 surfaces 2 sides of an interface. If you are sub soil and clay do you need anything between the 2?

Student: (Refer Time: 32:19).

We have to check whether you need a separator or not. If the subsoil is clay and you are putting clay on it is there a problem.

Student: (Refer Time: 32:32).

If the subsoil is silt and you are putting a clay on top of it is, there a problem the clay particles will not go into silt particles. They will meet something called a filter criteria if you are putting clay on sand is there a problem. Could be I need some criteria because then all the voids are getting bigger and if there is gravel and I am putting clay on top I can jolly well say when I put the clay on top it will go into the voids. So, whether I need a separator or not somebody use the word protector I do not need a protector for the underground soil, even if it is soft clay I need a separator, this clear.

So, I need a separator. I may or may not require it therefore, it is not in the minimum guidelines the designer has to decide, but I need to be very clear that I have something which has to be put here. So, I am just going to put a dash line and you can mark it as a separator optional separator is optional and then let us look at the interface between the geomembrane. And the compacted clay liner do you need a filter do you need a protector or do you need a separator between this. And this geomembrane it is plastic clays very fine grain and if you put anything you no longer have a composite liner. The intimate contact is an essential component of the liner do you need anything on the top.

Student: (Refer Time: 34:19).

Between the sand gravel and the geomembrane.

Student: (Refer Time: 34:25) protector.

A protector if you have angular grains, but if you have rounded particles you may not need it when will you get angular sand coarse sand, and when will you get rounded coarse sand and gravel.

Student: (Refer Time: 34:42).

You sure we close to a river and the riverbed has got round cobbles pebbles coarse sand gravel you can use it and typically that does not cause a problem, but if you have quarried material it is likely to be angular. So, again you need a protector here optional you may need it you may not need it. Is there another interface between the waste and the sand gravel? Do you need anything between them a filter or a separator?

Student: Separator (Refer Time: 35:25).

Or both I mean I have not said that you need only one you may design a filter which is hydraulically competent, but it may not be competent for a glass to cut through it. So, you need a filter definitely why do you need a filter.

Student: (Refer Time: 35:49).

If you do not put a filter still the flow will come down. Why do you need a filter? You said I need a filter just because I say you need something you do not want to put it. So, so if you do not put a filter what will happen?

Student: (Refer Time: 36:11) waste particle.

Waste particles will go into that. So, you need a separator or a filter.

Student: Filter (Refer Time: 36:17).

Will you said if you want to prevent particles from one to go into the other you need a separator?

Student: (Refer Time: 36:22).

The art.

Student: (Refer Time: 36:31) allow the leachate (Refer Time: 36:35).

So, separator may allow the water to go through. So, you need a separator and a filter. Please understand what are we bothered about. We are bothered about the fact that the fines of the waste should not come down and clog the drain. That is like your kitchen waste in your kitchen drain. If you keep on putting your tea leaves, you do not put them in the dustbin, but you keep on putting them in your drain they will go and clog the drain.

Similarly, the waste is heterogeneous it will have some fine particles. If you do not have a filter what will happen to the fine particles they gradually come down with the leachate the leachate will wash off because it is inclined, but it will deposit those fines in the sand and the gravel voids. And the sand and the gravel voids which started with 10 to the power of minus 2 will become 10 to the power of minus 5 and a leachate head will build up and you will have a huge landfill sitting on a wet sloppy a low strength material which can cause failure. And most of the landfill failures occur because of high leachate head. So, you need a filter and a separator. Well I am not going to write this, but I want to put this here. So, a filter and a separator a protector what is?

Student: Separator.

Separator and a filter; suppose water is leachate is coming through a geomembrane tear, we do not want it to stop it. Because then the compacted clay will become soggy and saturated, it should be a sigh a separator, but it should also be a filter it otherwise a geomembrane can be a separator. Please remember, but a geomembrane is also a water

barrier. So, we do not want water to accumulate in the clay, if you ever take a clay sample which is well compacted and saturated with the water it will gradually lose it is strength.

Now, the cause of this all that that we discussed is written here. Between the waste and the leachate collection layer between the leachate collection layer overlying the geomembrane, between compacted clay overlying the secondary leachate collection layer if you have a secondary leachate collection layer at the bottom it is gravel in which case, this is sitting over gravel. And you definitely need a separator and a filter or if you are depending on the subgrade.

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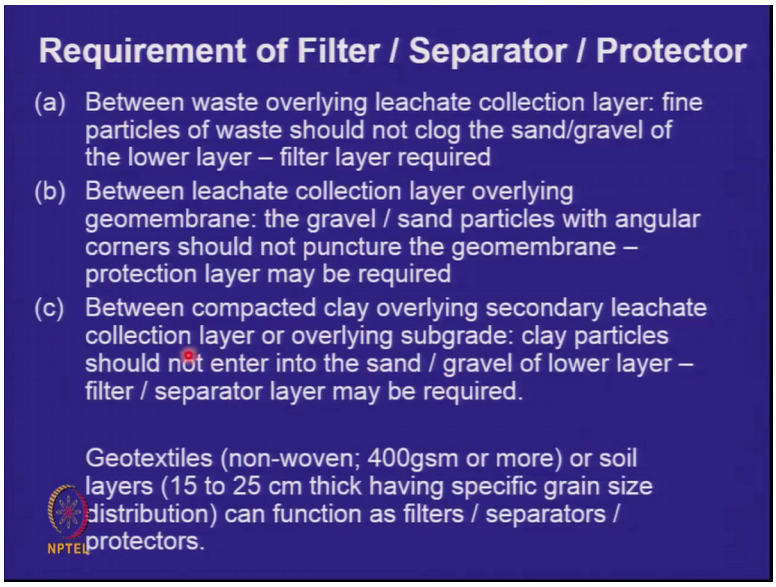

You can use 2 things as you can use 2 things as a filter and a separator and a protector we can use soil. So, remember traditionally we have been using soil our transition filters are made of soil; however, we have to apply a filter criteria you remember the filter criteria.

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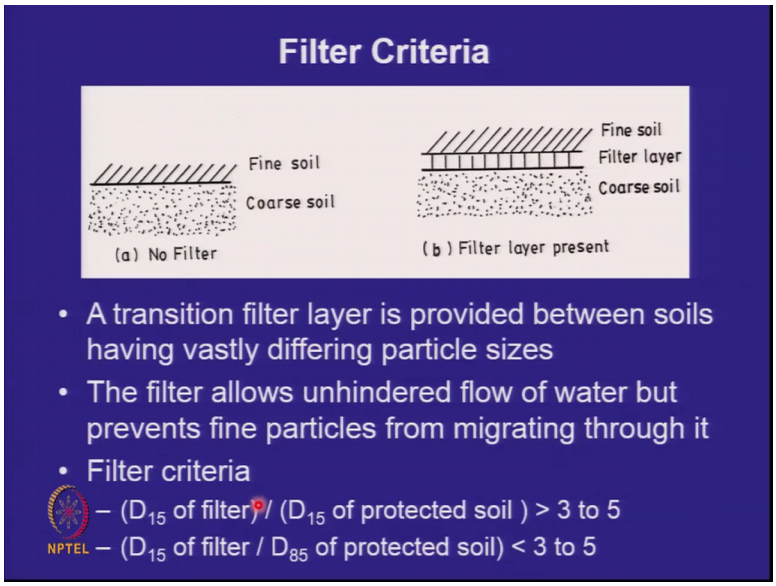

Let us try and remember it we have a filter criteria, which we do between shell and core d 15 of the filter should be more than d 15 of the protected soil. So, that water can pass. So, your filter cannot be less permeable than what it is protecting then the water will hold in that material. So, d 15 of the filter should be more than d 15 of the protected soil by, but d 15 of the filter is what is in front of it should not be. So, large that the fines can pass; that means, the d 85 of the soil behind which is being protected, should be less than 3 to 5 this is the filter criteria that we have used for designing inverted filters for designing transition filters. You have done slope stability and dams you run a course on dams you are doing it this time.

So, when you are doing dam design, please ask that this issue be addressed. So, that you understand the filter criteria, but the first criteria are that the filter is more permeable than the soil behind it. And the second is it is not that permeable that the fines can pass through it right. So, using these filter criteria, you can get the type of soil. So, you can always put a soil filter between the layers. I have got a geomembrane and I am going to put angular gravel on top of it. What would you use as a protector that the geomembrane is not effective? If you were if you if you want to use a soil what would you use in Delhi, I want to put gravel as the drainage layer, and I can only get quarried gravel. So, I get it quarried it is angular I am worried about my geomembrane what would you do as a protector.

Student: (Refer Time: 41:56).

I put Yamuna sand fine sand. Fine sand particles are fine it rounded because or sub rounded because they are riverbed material they would not puncture the geomembrane. So, there is a traditional material which is available. You may how much how much will you put may be only 15 centimeters 10 to 15 centimeters you just put a layer.

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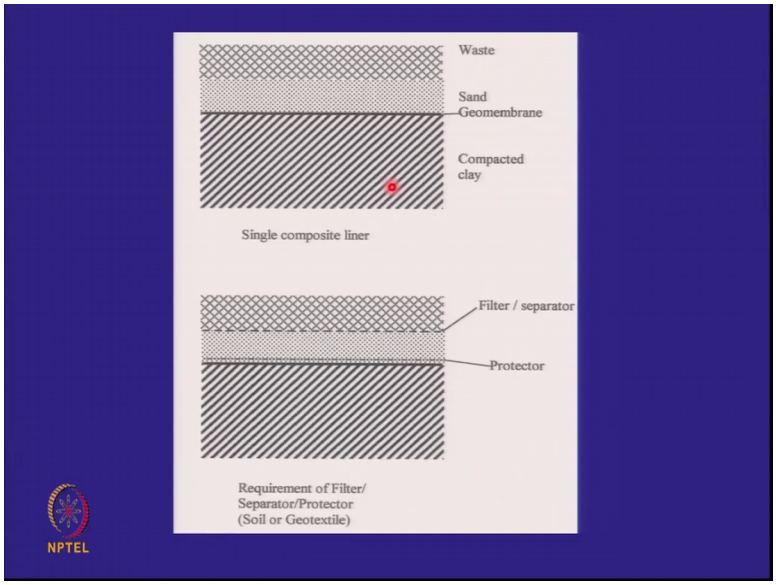

So, when you dump the gravel on top it should not damage it and when the load comes it will be distributed through those fine part, but you have other alternatives also. So, if I am to look at what do I use as filters and separators, I can use a material called geotextile or I can use soil layers the soil layers are 15 to 25 centimeter thick. They have a specific grain size, and can function as filter separators and protectors. Geotextiles are something that you will study in your course on geosynthetic.

But in a very coarse way they are like blankets, thick blanket not a quilt a thick blanket. Now if you have a thick blanket they are blanket is pervious, but you can. So, design it artificially that it is fines will not go through it, but water can go through it. So, you can use geotextiles as separators or filters and protectors, but there is a design involved in it at the moment. I have used 2 words here you can note them down they are normally you are using nonwoven geotextiles and 400 GSM is their eight is 400 grams per square meter. I mean it kind of a indirect indicator of the thickness or the strength, they more the GSM, they more the strength.

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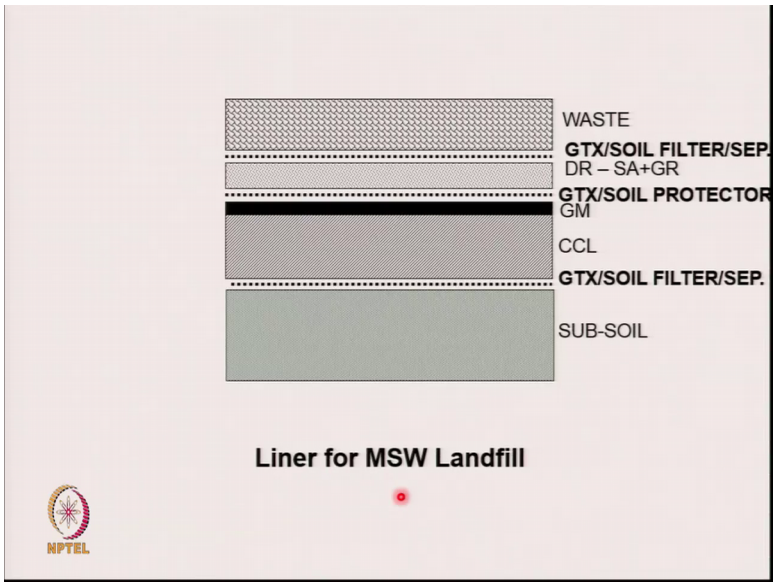

So, just to finish this is what our liner will now look like for a municipal solid waste. This is what a liner will look like for a municipal solid waste, I have waste. Then I have a filter oblique separator, it can be geotextile GTX. So, geotextile or it can be soil, then I have my drainage layer or leachate collection layer sand and gravel.

Again I have a GTX soil protector, I have my geomembrane I have my compacted clay liner I have another filter oblique separator of GTX or soil and then I have my subsoil; so, 1, 2, 3, 4, 5, 6, components of a liner system for a municipal solid waste, single liner if you have double composite liner many more. This is the natural soil which exists this is the waste we are going to put 1 2 3 4 5 6 is that right.

So, we will stop here and carry on in the next class about liners for municipal solid waste landfills. Thank you any questions you are welcome to ask. No questions? All right, we will take it on from here.

Thank you.