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

Prof. Manoj Datta
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 15
Covers for Landfills - Part 2

Good day to all of you and welcome back to this class in which we are going to continue our discussion on Covers for Landfills. Last time we talked about several layers in the cover system; surface layer then next.

Student: Protect (Refer Time: 00:43).

Protection next.

Student: (Refer Time: 00:44).

Next barrier, next gas collection and then foundation.

So, many layers and so, many interfaces and so, many separators and filters in it, but I talked about replacing some of these layers with manmade materials.

(Refer Slide Time: 01:11)

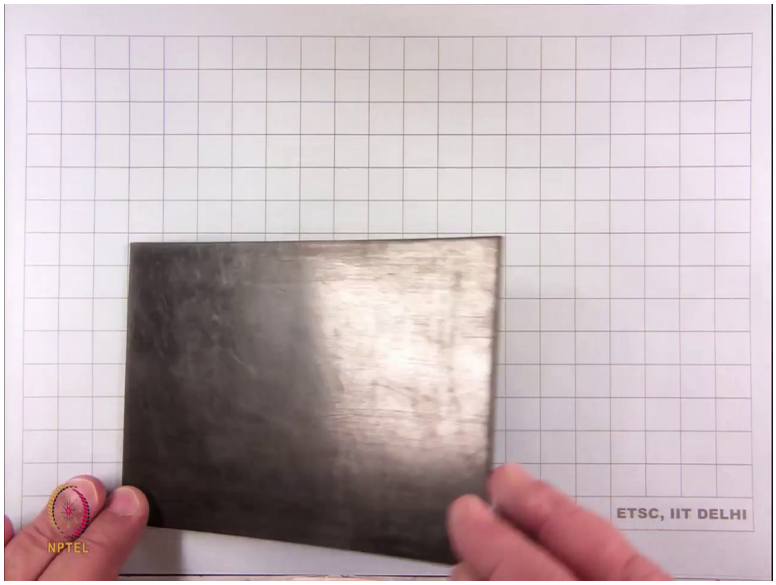
So, what I am going to do is let me see whether I am going to show you some of the materials.

(Refer Slide Time: 01:14)

So, here you will see that in the drainage layer we have a sand and gravel layer and below that there is written Geonet overlying geomembrane and there is another word called Geocomposite.

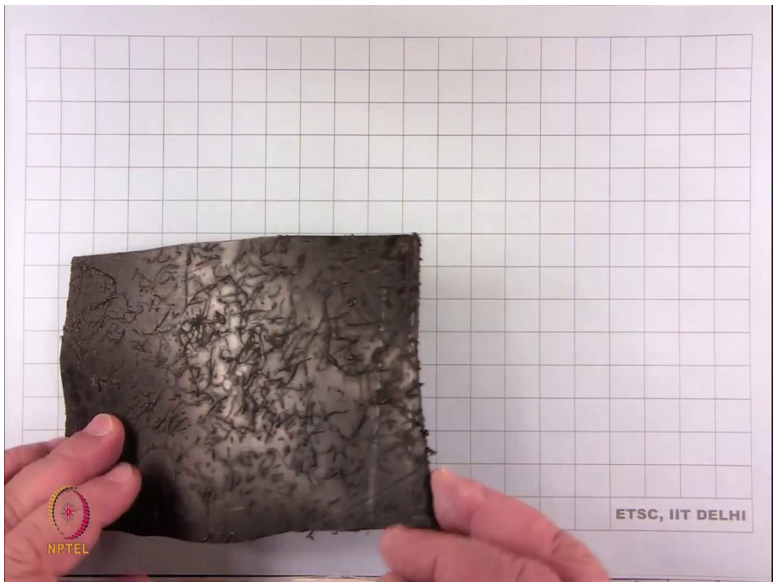
We also we all seen a geomembrane last time right now I am going to do with you Geonet overlying a geomembrane and I am going to do with you Geocomposite. So, first I am going to show you these specimens and then we will carry on the discussion from here.

(Refer Slide Time: 01:53)

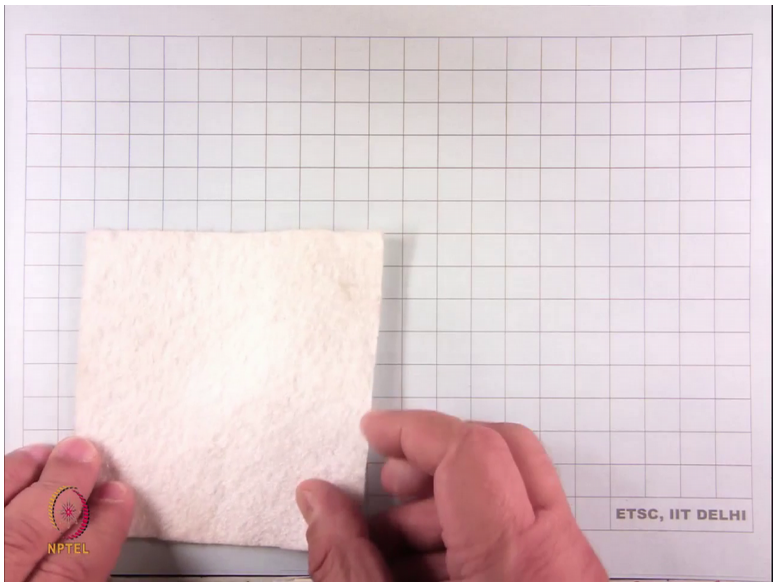


So, let us see starting with a geomembrane then a Geonet and then a Geocomposite. So, we all remember this smooth geomembrane and we also all remember rough geomembrane and this is going to become very important in covers.

(Refer Slide Time: 02:02)

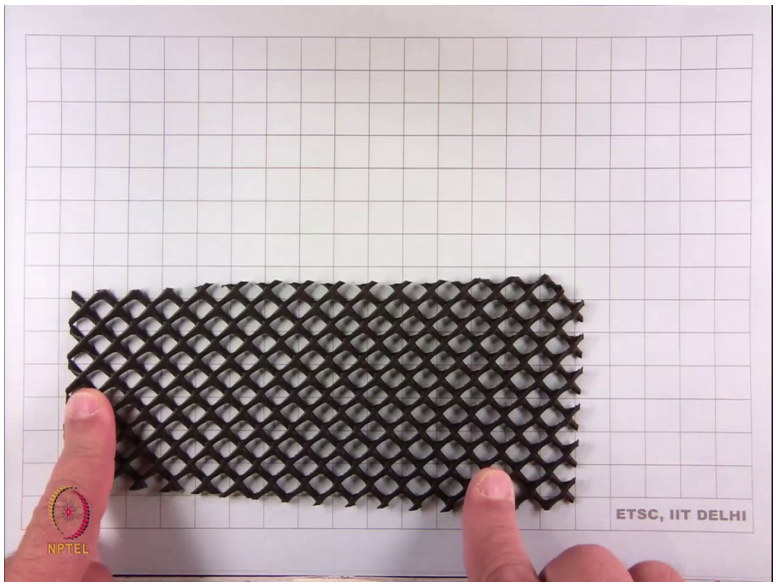


(Refer Slide Time: 02:11)



Now, I am going to show you we remember Geotextile; nonwoven Geotextile. Right now I am going to show you a device sorry a material which looks like this its looks like a net right, it has a thickness of few millimeters and suppose I have a geomembrane.

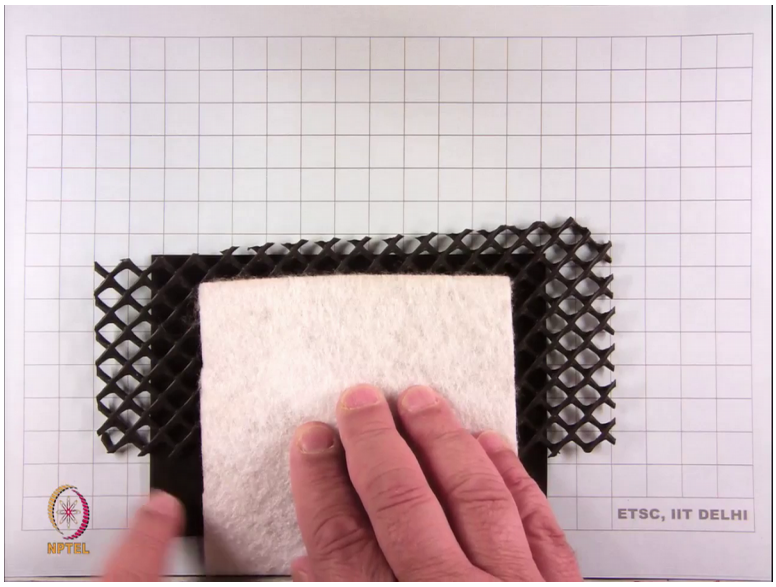
(Refer Slide Time: 02:19)



I am taking a geomembrane and putting this net on top can this net replace the sand that is the question the water will be percolating down from the surface layer and the protective layer into the drainage layer it will come and rest on the geomembrane.

If I have a net on top which means there is a finite thickness of airspace on top and if this is sloping downwards if this is sloping downwards then water can flow along the plane like that along.

(Refer Slide Time: 03:25)



This I am bothered about the fact that fine should not come into this. So, what will I do to prevent fines I will put a separator. So, now, I have a material geomembrane at the bottom a Geonet at the top and filter Geotextile above it.

You will learn more about Geonets in your course on geosynthetics, but if this can replace the sand. So, something which is 5 to 10 millimeter thick is replacing the sand provided it has the capacity to carry the same amount of water as the sand that we had right. So, we will be dealing with issues of permittivity and transmissivity in this material, but this is one set of options.

Now, so, that it should not be difficult to install it in the field we have something called a Geocomposite what does it look like from the top is it a geomembrane or a Geotextile.

(Refer Slide Time: 04:14)

Student: (Refer Time: 04:19).

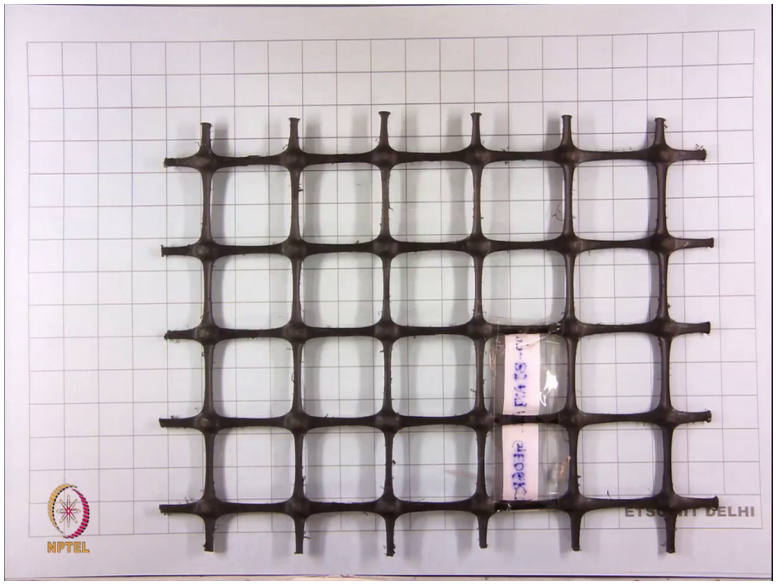
Very good, this is a Geotextile it is a nonwoven Geotextile it looks like a blanket on both sides if I see I have a Geotextile, right, but there is something inside it if I look at it can I see some black-black things. So, what is inside it let me try and peel off a corner and decipher this for you if I peel off the corner what do I see?

Student: (Refer Time: 04:48).

So, there is a Geonet with a Geotextile on top and if I look at the other side it has got a Geotextile on top this is bonded to it. So, what is the advantage of this; this comes in the form of a roll a big roll. So, you are able to this is another one I can show you a thicker one this black carbon black carbon black if I peel off one of the corners you can see a Geonet. So, this comes in the form of a roll and it can be laid on top of the geomembrane.

I have a geomembrane and on top of it I have a Geocomposite. So, this replaces the one-fourth thick 30 centimeters thick sand layers and it should have the capacity to drain away the water and before I move away from here I also want to show you one more material.

(Refer Slide Time: 05:59)

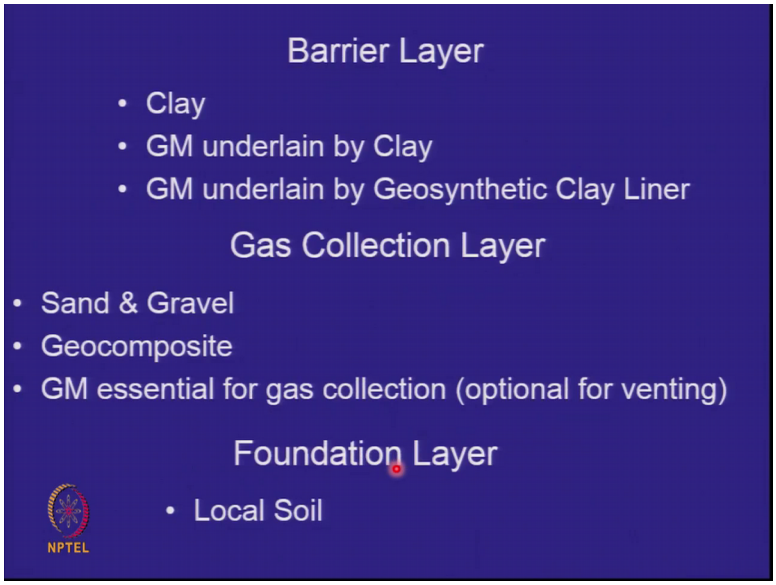


Which looks like this it is called a Geogrid, it is a very strong material I mean if I gave it to you with your eyes closed you would have said. So, this is some metallic mesh.

It is a reinforcing material called a Geogrid this also you will study about it later, but we will introduce it to you in this class the difference between a Geogrid and geo Geonet is stock very small openings which are orthogonal to each other in the Geonet. These are at right angles to each other much larger apertures than in the Geonet, Geonet does not have much strength it is not for strength it is for in plane flow of water, whereas Geogrid is like a reinforcement a mesh a reinforcing mesh.

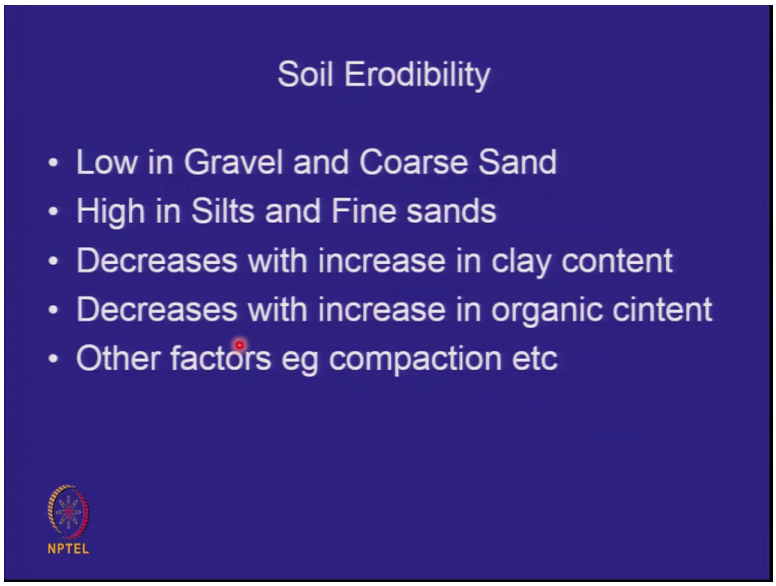
So, when I look at the materials here I am saying I can have a drainage layer made of sand and gravel or I can have a drainage layer made of Geonet overlying a geomembrane. So, on the geomembrane you can put the Geonet on the Geonet you can put a Geotextile and on top of it you can put the protective layer this will be cheaper than a geo composite, but it will take some time to install it first you will put the geomembrane, then you will put the geo net, then you will put the Geotextile the 3 operations.

(Refer Slide Time: 07:47)



If the Geotextile; if the Geonet plus the Geotextile is available as one unit its one roll. So, the number of operations in installation goes down. So, that is a Geocomposite. So, I can use a Geonet overlying a geomembrane for drainage or I can use a Geocomposite and the same can apply to a gas collection layer the same can apply to a gas collection layer because gas will flow at a faster rate in a Geocomposite than water.

(Refer Slide Time: 08:05)



We are worried about a erodibility of the topsoil. So, as we said gravel is low in erodibility and course sand is low in erodibility soils which have high silt content and fine sand content they are the ones which erode the maximum, will clays erode more than silts or less than silts?

Student: Less than cell (Refer Time: 08:32) less than (Refer Time: 08:33).

Because the clays of finer particles the finer the particle the more the erosion.

Student: (Refer Time: 08:38).

Because of cohesion.

Student: Cohesion.

Clays of net negatively charged particles they remain plastic in nature they have a cohesion.

So, as the clay content increases the erode ability decreases also it is observed that when you have organic content in the soil its supports vegetation and therefore, it decreases erode ability. So, the best materials for low erodibility are gravel and coarse sand followed by clays with high organic content then silt and fine sands have a erodibility prop if you grow vegetation on silts that is fine they are not going to erode.

But, before you are able to establish the vegetation remember you are going to have a landfill on which you are going to put all these soils then how much time do you think that you can grow grass on soil a day an hour a week a month

Student: 10 days; 15 days.

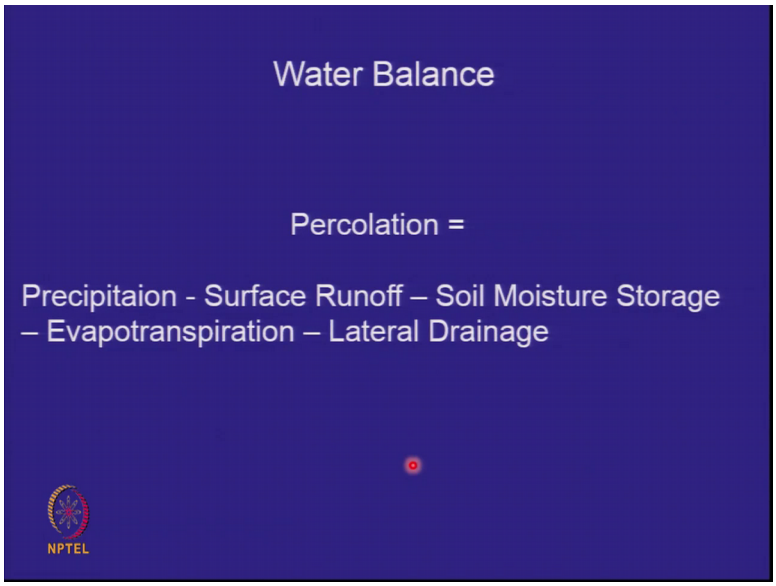
Well, I would like to see the magical grass it has been said that you can grow grass in 10 to 15 days. I can transplant the grass from one location to another, but for a proper grassy cover to get formed it will take a month or more or you have to get these cut pieces of readymade grass these are much more expensive to be placed on the soil. So, the issue is that till the time the vegetative cover gets established we are faced with erodibility problems.

(Refer Slide Time: 10:27)

So, before the monsoons please have your vegetative cover in position.

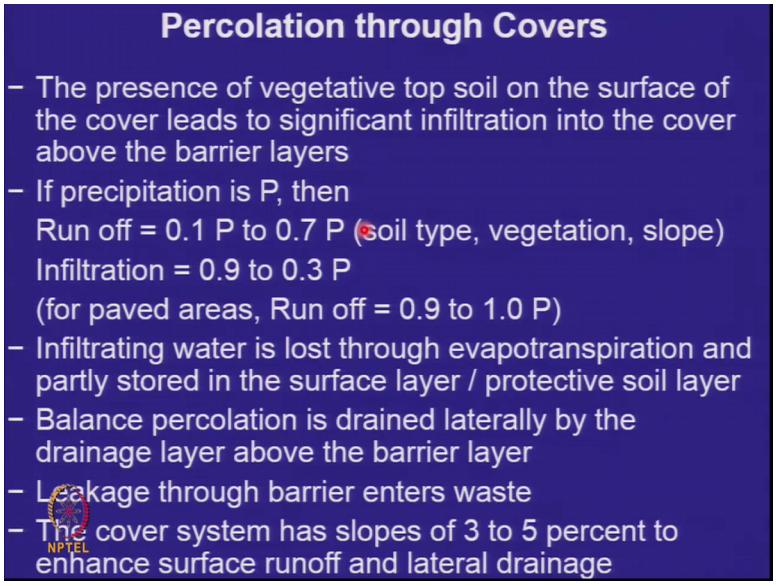
So, some of the cover design aspects which we are going to deal with are the components and their specifications the thickness of the components we have done this the separators protectors and filters we have looked at them we are going to look at stability of slopes we are going to look at erosion control we are going to look at surface water drainage gas collection systems and the influence of settlement and subsidence on the materials that we use.

(Refer Slide Time: 10:55)



First remember that how much water is percolating into the waste is precipitation minus the surface runoff minus the soil moisture which is stored inside the soil we have to remember that that the topsoil and the protective layer is not totally saturated. And if it is not saturated it will store some extra water beyond the field capacity it will come down and Evapotranspiration is also something which makes the water go back because now you are having vegetative growth at the top and then finally, lateral drainage.

(Refer Slide Time: 11:46)

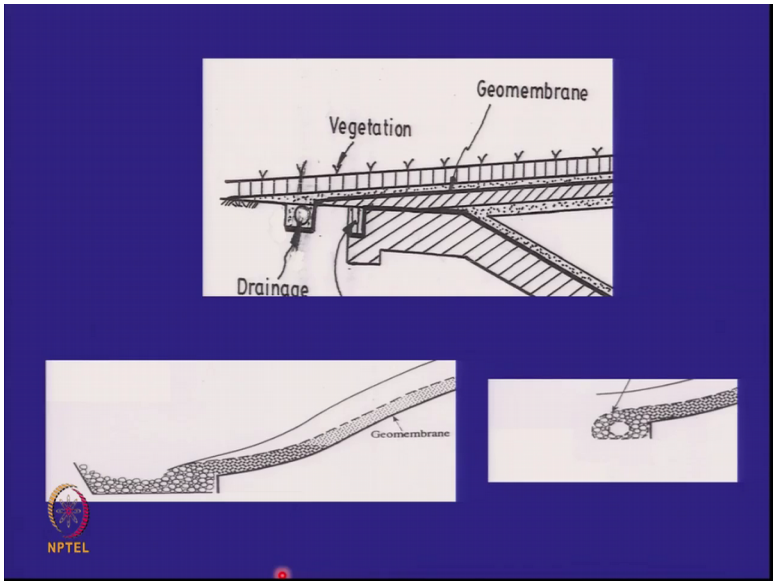


So, after all this is removed do you get percolation below the barrier layer? So, if precipitation is p then typically the runoff depends on the type of soil the vegetation the slope, but runoff will be high when soil is fine grain vegetation is well established and slope is high, but if precipitation is falling on gravel what will happen its coarse grain vegetation cannot grow on gravel the water will go end.

So, depending on the soil you will have infiltration which may be ninety percent to 30 percent of the precipitation for paved area as I said all the water runs off and infiltrating water is lost through Evapotranspiration and partly stored in the surface layer and the protective layer balance percolation is drained laterally leakage through the barrier enters the waste and typically to enhance surface runoff to enhance runoff we are giving at the top a slope of 3 to 5 percent to enhance the surface runoff and lateral drainage.

So, remember all your covers are convex all your covers are convex there are no covers which are horizontal 3 and 5 percent are significant slopes on the cover.

(Refer Slide Time: 13:16)



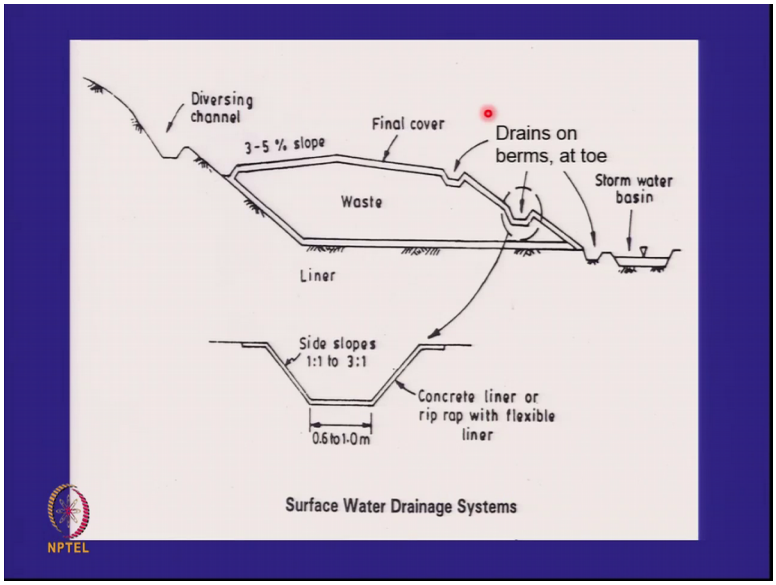
So, if I look at it when my water enters into the drainage layer which is above the geomembrane or above the barrier where does it go it goes down the slope and it goes into a drainage pipe is this Leachate this is like surface runoff.

So, please understand the rain is falling on the surface right this water which is falling on the surface will also runoff it will go to the storm water drain here this water will also

come to a drainage system which would be connected to the storm water drain only the water which goes into the waste becomes Leachate and goes down. So, you can have several arrangements you can have an arrangement like this which is the same thing here or you can have a trench made of cobbles and the water can be taken out in the storm water drainage system.

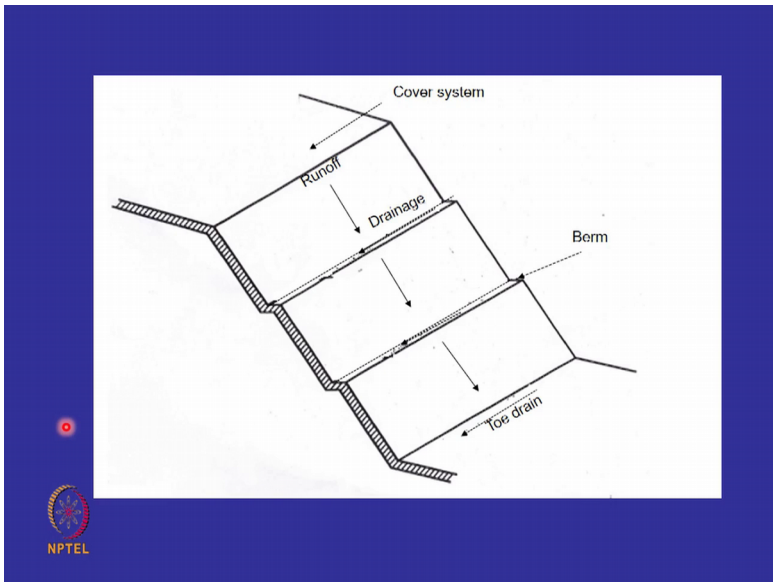
So, this is important in some of the landfills this detailing is not done properly you know what happens this becomes connected with this is a very small distance if you leave this somewhere here it is sort of reverse flow into this in this connection is very important you should have no chance of the water which is coming from here going into the landfill this junction is very important we will do it later.

(Refer Slide Time: 14:46)



Which landfill is more affected by surface water above ground or side slope landfill the problem is the moment you have side slope landfills the water is coming down the slope it will tent to accumulate. So, as I said you have a 3 to 5 percent slope here and 3 to 5 percent slope here this slope which I am talking is at the top of the cover it is not the side slope the side slopes have a different value which we will talk about.

(Refer Slide Time: 15:36)

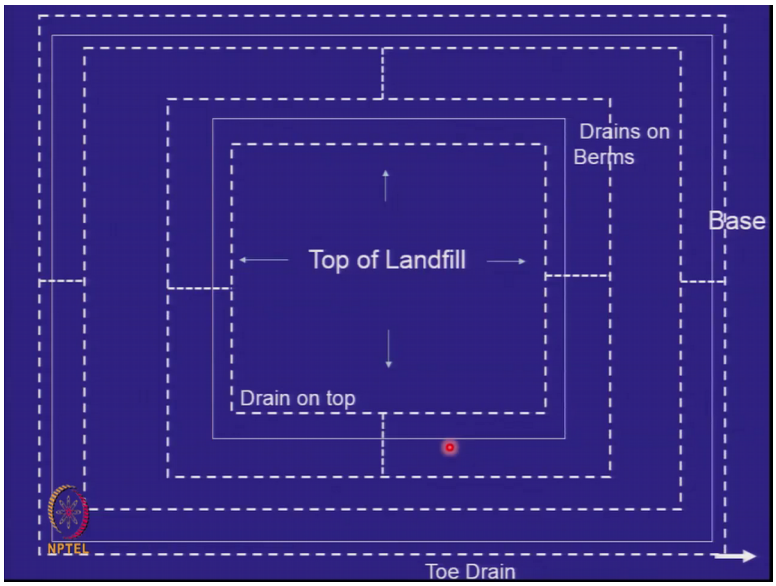


So, please see the arrangement you will have a diversion channel or an interceptor channel which should not allow the water to come on to the landfill whatever falls on top of this should go out from a drain here and a drain here and a drain at the berm and should go to the storm water drain at the toe and a better view allow the water to runoff down have a berm; down have a berm; down have a berm on the berm have a drain to collect the water.

If there is no berm the slope may be stable, but once it is more than 8 meters in height the water velocity becomes very high. So, long slopes without berms; what happens the erode you starts because the velocity of the water is high these berms act as energy dissipaters the water comes down and it is collected.

So, it is good to have a berm and the berm is 3 meter wide because you have a road on it as well your inspection road and the drain is only at one side of the inspection road. So, very important detailing for a landfill if you can collect most of the surface water all your problems are solved if the surface water cannot runoff the landfill top it is going to go inside its going to go nowhere else than inside.

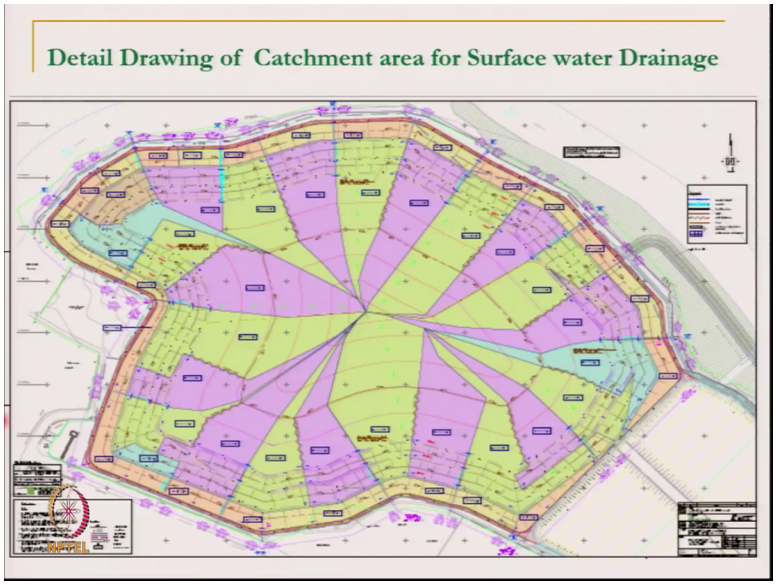
(Refer Slide Time: 16:48)



So, we should take care of the surface water very carefully if I look at a top of a landfill from aircraft or a drone; let us say this is the top of a landfill. So, what will you find 3 to 5 percent slope 3 to 5 percent slope 3 to 5 percent slope 3 to 5 percent slope then have a drain here this captures all the water which is falling on the top these are the 2 berms. So, there is a drain here on the berm.

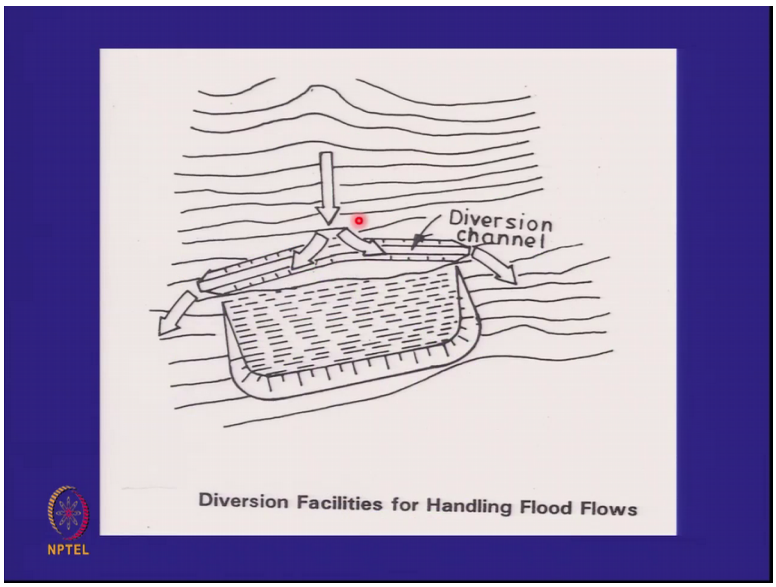
So, whatever is captured in this drain has to be connected to this drain down the slope and whatever falls whatever rain falls between these 2 drains also is connected in this drain then it goes to the next berm and finally, it reaches the toe drain and this is all surface water runoff. So, it can go into the storm water drainage system of your landfill very very important you have a convex top, but you are collecting it if I; if I look give you an engineering drawing of a landfill have a look at this.

(Refer Slide Time: 17:49)



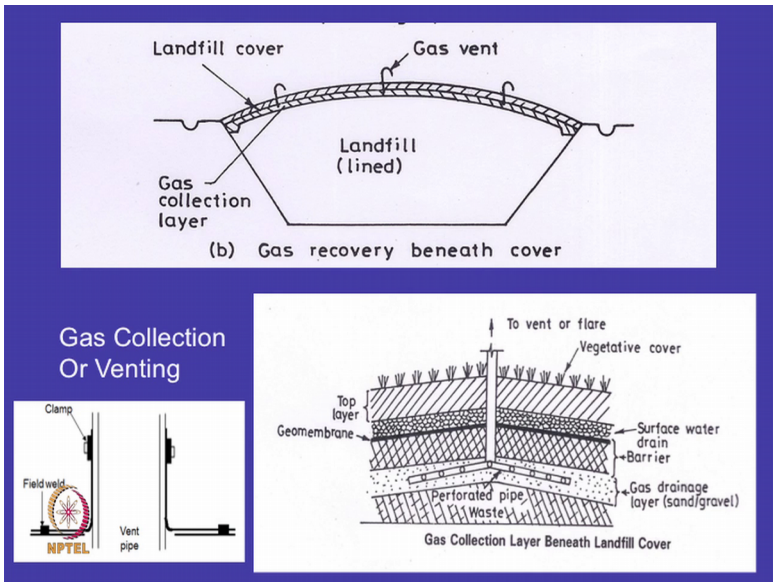
This is the way the land it was available and this is the landfill area and you can see a lot of contours right, but you can see on this it has got a every area from which the water will be connected where is it flowing where are the drains what are the cross connectivities and eventually they will reach a toe drain at the bottom. So, I cannot; the details do not stand out, but remember all these are drains which are collecting the water and sending them to a toe drain which eventually gets connected to the drain storm water runoff drain here.

(Refer Slide Time: 18:32)



And this is the concept of the diversion channel or the intercepted drain if you are on a side slope landfill please catch the water and divert it from the sides do not let it enter the landfill.

(Refer Slide Time: 18:45)



The other thing we talked about was a gas collection layer right and please understand 2 concepts the concept of venting and the concept of gas collection for energy recovery venting means you are still allowing the gas to go into the atmosphere, but venting means that the gas goes to the atmosphere in specified vents suppose today you have developed the landfill you do not have the money to collect the gas and convert it into energy you do not have the investment.

You put in vents. So, that tomorrow you can attach a pipe to these vents and collect the gas. So, one can be a cover with no vents in which case the gas will pass through the defecation crack and the high permeability zone and go to the atmosphere the other is you have the gas collection layer. So, the gas collection the collection layer and the pipes has holes in it perforated pipe and it goes up the vent.

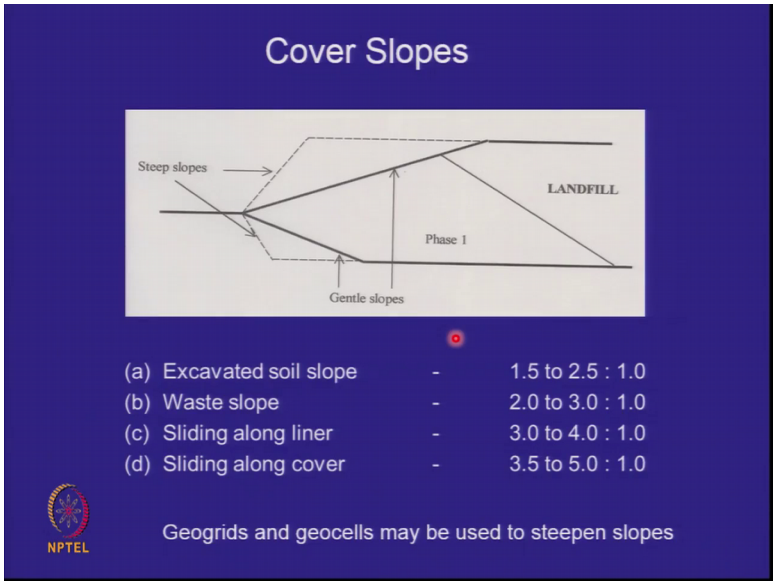
Which basically is nothing, but like an inverted u does not allow the rain water to come in and comes out from these vents and if you are using a geomembrane then please note that a connection between the geomembrane and the vent is very important otherwise water will start going from the side of the rigid element when you put a pipe in soil after

some time you will find there is a little bit of separation depending on whether summer water will try to go in and create more Leachate.

So, you have to put the geomembrane around it to clamp it properly. So, then I want to recover gas for energy please understand you will have this gas collection layer at the top, but you will also have deep gas collection wells which are not shown here. So, this are not trying to show you gas collection for energy recovery I am trying to show you if you make a normal landfill on a municipal solid waste dump and even if you are not using a geomembrane on the top please put the vent pipes because you will put a gas collection layer it is mandatory once you put the gas collection layer you should be able to collect the gas through the vent in the future if you want.

You see today there are no restrictions on greenhouse gas emissions tomorrow there may be international law which will say that all landfill gas will be captured and burnt flared. So, that methane gets converted to carbon dioxide.

(Refer Slide Time: 21:25)



So, we need to have these vents in all locations I talked about the importance of cover slopes cover slopes is I am going to remain exposed for 50 to 100 years.

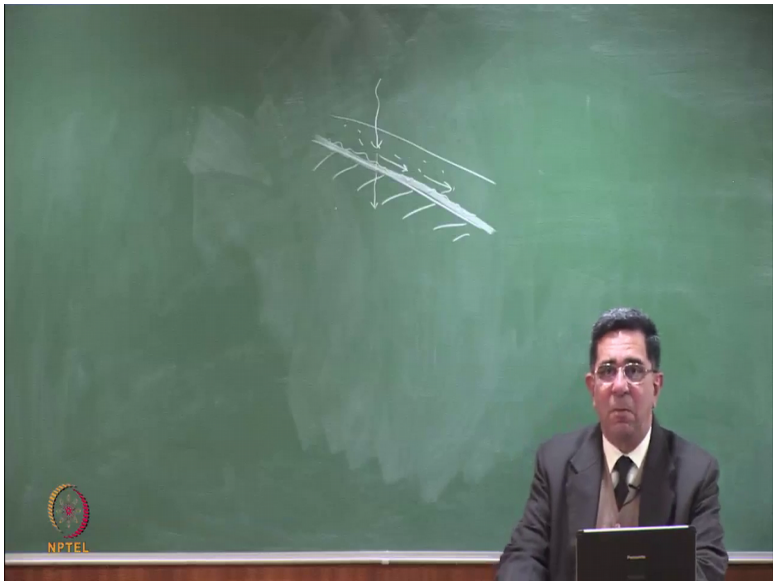
The operator always wants to make very steep slope. So, that we can store more waste and we would loved have vertical slopes, but we need to look at the slopes we have this slope the cover slope we have the liner slope in excavation and we have a waste slope.

So, typically when you excavate soil you will find that slopes of 1.5 to 2.5 horizontal is to vertical please note I think is not written here.

This horizontal is to vertical. So, they are flat one is to one is 45 degrees this is flatter than 45 degrees these are usually used in soils we also use similar slopes for the temporary waste dump the slope is created because I am filling the waste like this. So, I have a temporary slope. So, this is also kept at 2 is to 1; 1 is to 1 point, but along the liner and along the cover the slopes are even more gentle.

If you look at the cover we are talking of slopes of 3.5; 5 is to one very flat slopes. So, you wonder what are these geotechnical engineers doing that they cannot make this one is to one traditional slopes which you have the soils one point 5 is to one and also along the liner the problem is you have put a geomembrane the moment you put a geomembrane it is a slippery surface 2 things happen water will get stuck at the geomembrane and start to travel along the geomembrane.

(Refer Slide Time: 23:26)



So, I think we need to understand this suppose this is the slope this is my clay compacted clay barrier and this is my geomembrane whether it is in the cover or in the liner it is the same. So, I said smooth geomembrane are troublesome because the angle of shearing resistance is low let us make it rough. So, I can make this rough. So, now, my angle of shearing resistance is not low; however, what is happening I have a drainage layer on top

water is coming down leakage water or Leachate or surface water at the top if you see surface water coming through the protective layer.

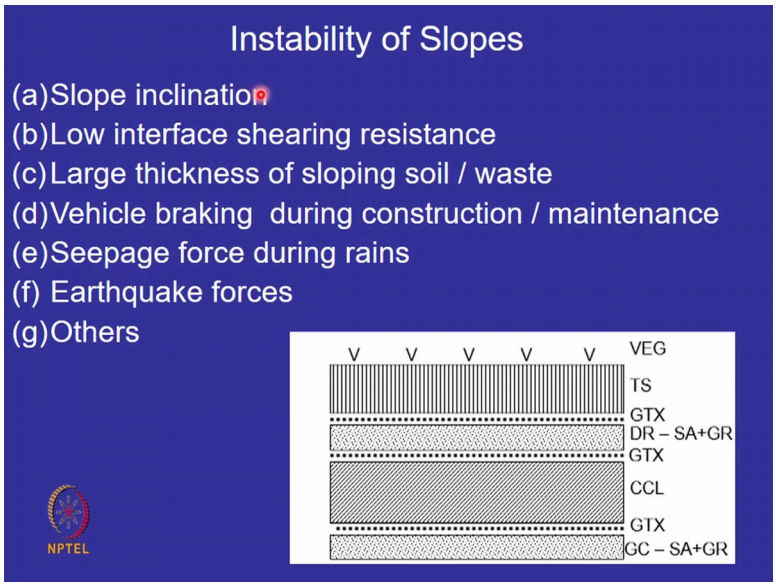
Normally the geomembrane was not there it would go and hit the soil it would be first make the soil more wet and then it will go down. So, this was the original travel in soil water all this travels, but what happens is you hit geomembrane it is like hitting rock. So, what happens in hilly regions water is rain falls on the slope water goes down where it hits rocks what happens it starts to flow along when it starts to flow along at the moment the seepage forces are downwards, but the moment it starts to flow like this the seepage forces are down slope it is destabilizing in the force and therefore, that is the cause of instability.

So, 2 causes of instability one too many interfaces 2 flow occurring along the slope downwards and this causes the slopes to be flat in the liner it does not matter your excavation is going to be there for a year at max 2 right then the waste would have reached the top the waste should have been filled. So, the slope no longer is instable because there is a stabilizing waste here, but what happens in the cover in the cover that is going to be there for years and remember just think of Bombay rain or wherever you come from if you are very heavy rain imagine it is taking place for 8 hours its falling on the slope bulk of the water is rushing off from the top right, because you are very good vegetation.

For 8 hours the water is rushing off the top and it is going into the soil and then it is rushing along the. So, water is rushing on the top downwards water is rushing inside downwards what do you think is going to happen to the soil if you do not design it properly it will definitely tend to move downwards unless you have designed it for flow stability. Therefore, the gentle slopes can we make them stable of course, we can make we can make anything stable.

We can make a vertical slope and put a concrete wall engineering solutions can be for everything, but the issue is would the concrete wall then serve as a liner or a cover or what and will it be able to take the settlements of the wastes behind it you put a wall and the waste settles what is going to happen to the wall. So, remember slopes of along the Geocomposites not the Geocompressor along the composite liner systems are very gentle we can make them steeper we will do there is a separate discussion on slope stability.

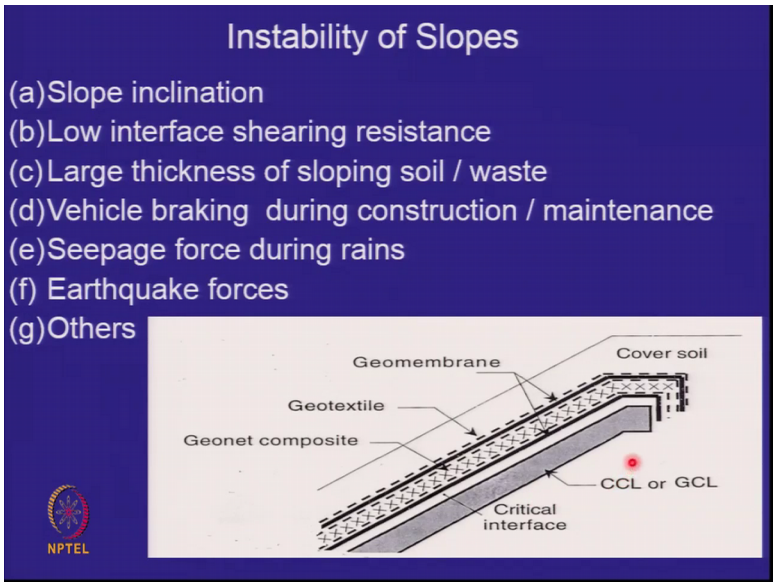
(Refer Slide Time: 26:49)



So, instability occurs because of slope inclination low interference interface shearing resistance no matter how rough I make my geomembrane it still is not having the highest phi dash large thickness of the soil on top vehicles will travel on this cover while you are making it seepage forces during rains earthquake forces will occur and others.

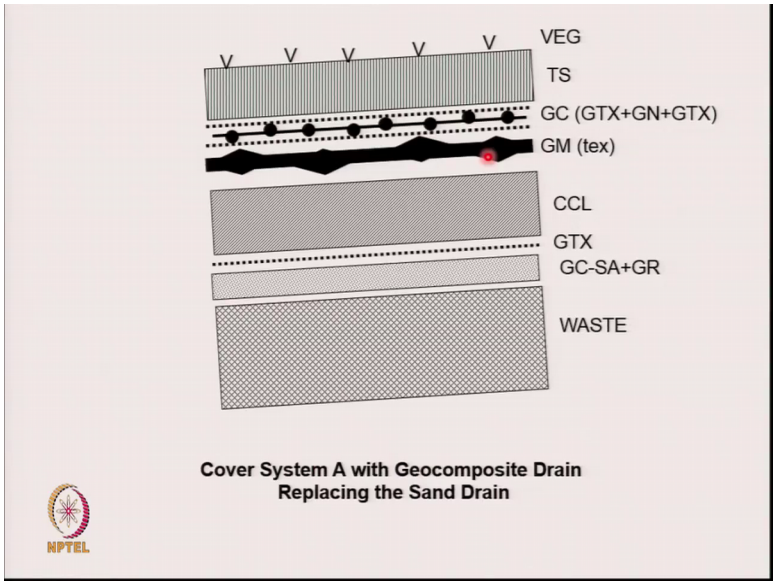
So, all these interfaces it is not just about the interface between the geomembrane and the soil suppose you have replaced the compacted clay liner with the GCL we talked about a Geosynthetic clay liner last time what is inside the GCL bentonite when the bentonite is hydrated it is like swelling soils fully saturated very low angle of shearing resistance. So, even this has a problem.

(Refer Slide Time: 27:43)



So, all these interfaces in fact, bentonite manufacturers will tell you that if you are going to make a slope steeper than 3 is to one you have to use the special bentonite which is got a special GCL which has got a reinforcement inside which does not allow failures to occur.

(Refer Slide Time: 27:57)



Look at this in detail, but I am just showing you some examples it is the same cover top soil drainage geomembrane compacted clay liner first people use we have been used to use smooth Geomembranes I made it little thorny. So, that you can get new way using

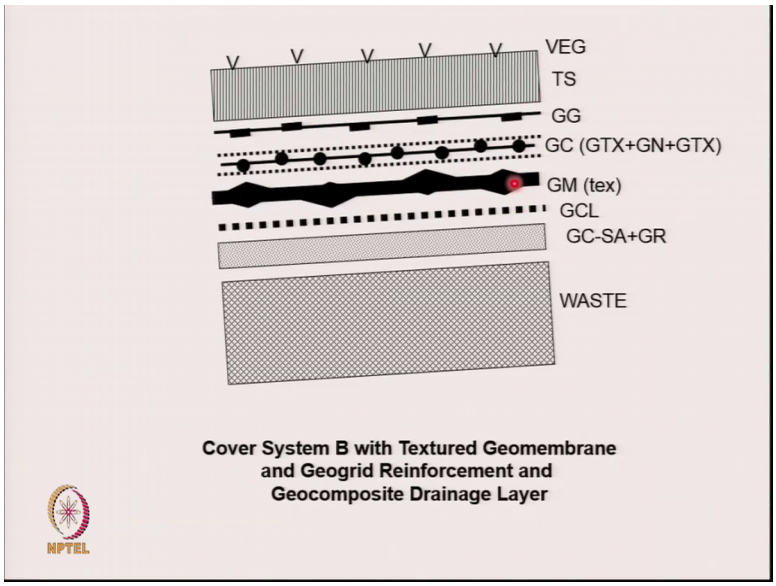
texture the question was first you only started doing texturing at the top making it rough at the top. So, that there was a good phi dash on the sand, but then now we are texturing at the bottom as well. So, that there are good roughness with the clay as well.

Now, how do I how do this cover options change because now I told you about Geocomposites, Geogrid here if the if the soil is too steep and this soil is slipping down I can put a Geogrid I showed you a Geogrid a reinforcement I can put a mesh inside the soil and hold it on the top by anchoring it in a trench. So, soil wants to go down factor of safety is below acceptable the Geogrid is holding the soil this you will study about more in geosynthetics.

I have a big problem the sand is one foot thick it is too heavy and w cos alpha remember the downward force is pretty high you have done slope stability you are doing slope stability look it is as slope stability of infinite slopes I want to reduce the thickness of the sand what do I do I go in bio geo composite geo composite is only about 10 millimeters thick we just showed you one light weight. So, the w is decreasing therefore, the download force is decreasing.

So, here you have a geomembrane which is textured the Geocomposite and the other layers on top even better you do not want to use compacted clay at the bottom we are not getting clay let us use the GCL I am not a strong proponent of GCL whenever you want to use GCL you need to put a thick low permeability soil beneath it, but these are options which you can also consider, finally you may put a Geogrid.

(Refer Slide Time: 30:09)



(Refer Slide Time: 30:25)

A geomembrane with the Geocomposite and a Geogrid sorry I call this Geogrid this is the soil Geogrid which will prevent the sand for slinging off, but I can reduce this and put a Geocomposite instead of it and put a Geogrid this holds the whole soil together. So, a large number of alternatives as you can see with natural materials and manmade materials currently in the developed world a lot of geosynthetics are being used.

In India we are still dealing a lot with natural materials, but gradually these are also coming into play, but be careful always design a system which will last for a long period

of time and not be affected by too much tears and punctures of the time of installation. So, this is a very nice final cover system of one of the landfills you can see grass you can see berms as I talked to you also have grains and you can see some vents.

(Refer Slide Time: 31:17)

This of course, is the temporary cover system before the monsoons come you have got waste here. So, it is stockpile in a temporary cover system.

(Refer Slide Time: 31:29)

(Refer Slide Time: 32:01)

This is yet another landfill grassy slope you can see this drain this is the storm water drain storm water drain at the toe these are the berms which are drains in it one 2 those berms allow the water to flow through this and this is all segmented prefabricated units why because the surface may settle. So, we allow the water it comes out to this and it is carried away is the laying of a cover system Geotextile geomembrane soil this is, finally trying to make vegetation grow before the monsoons come.

(Refer Slide Time: 32:12)

So, you are grading the soil and you have got grass you can see the kind of soil they are using.

(Refer Slide Time: 32:25)

They are using local soil, but start some gravel content can you see that and eventually of course, this is what it look like the story is that.

(Refer Slide Time: 32:36)

It this can also happen this is the drain which carries the water downwards this is the erosion which has taken place when you.

(Refer Slide Time: 32:41)

Make these layers very thin then the geomembrane can get exposed because you can slide along this. So, unless you have a good vegetative cover which is form and sustain if you make the thing very thin they are highly prone to erosion if it was thicker then at least we would have an erosion gully, but you would not have reached the level of a geomembrane.

(Refer Slide Time: 33:21)

This is also another short which my might have showed you this was temporary coverage before the monsoons. And this is a big contract they call a regular contractor who puts all

this thin geomembrane then he puts bamboo then he puts these sandbags because when you have gusts of wind.

(Refer Slide Time: 33:49)

It blows and this is the hazardous waste landfill. So, the more Leachate to make that gets produced the more money you have to pay for to the ETP and the owner wants to make profit.

(Refer Slide Time: 33:55)

(Refer Slide Time: 33:57)

This is the situation that is the final cover system with the soil on top and that is the green vegetative cover vent very expensive to maintain this looks like beautiful, but very expensive to maintain this you need to water it if you do not have water you have to buy the water.

(Refer Slide Time: 34:18)

So, at the this is the green landfill grassy green this is made of rubble masonry, but the pollution control board is saying is not green and 2 two issues here this if this is settles with time they are going to be large number of cracks we can repair it no doubt about it.

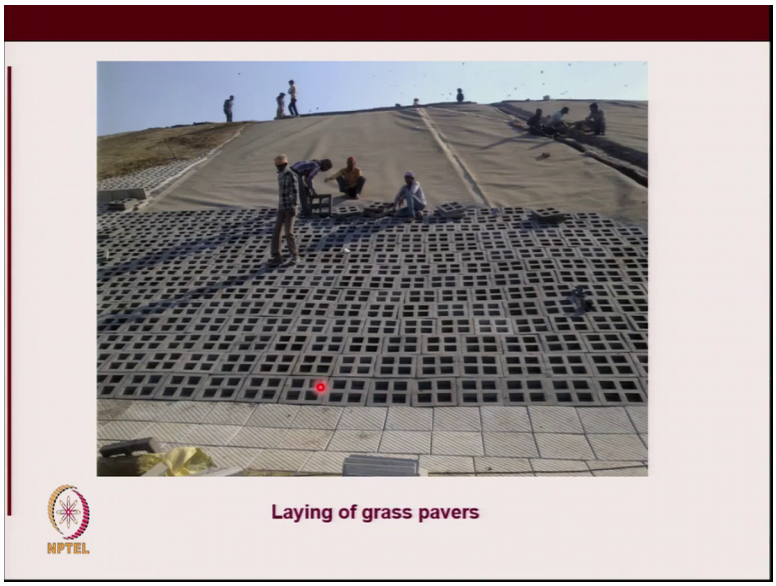
But this is hazardous waste landfill its not settling that much you cannot use this on a municipal solid waste will be there are huge depressions on municipal solid waste landfills with time. And then they are trying to make this green I am standing here looking at the green I am standing on the green looking at the rubble masonry and in rubble masonry now they are going jatropha to make it look green.

But children can come and play here of course, I am not saying the children should come on hazardous waste landfills, but you can have limited public use if you have a very intense monitoring system no gases or liquids are emitting out of it, but you cannot use you cannot come and play on the rubble in masonry and here are more efforts to make the rubble masonry green.

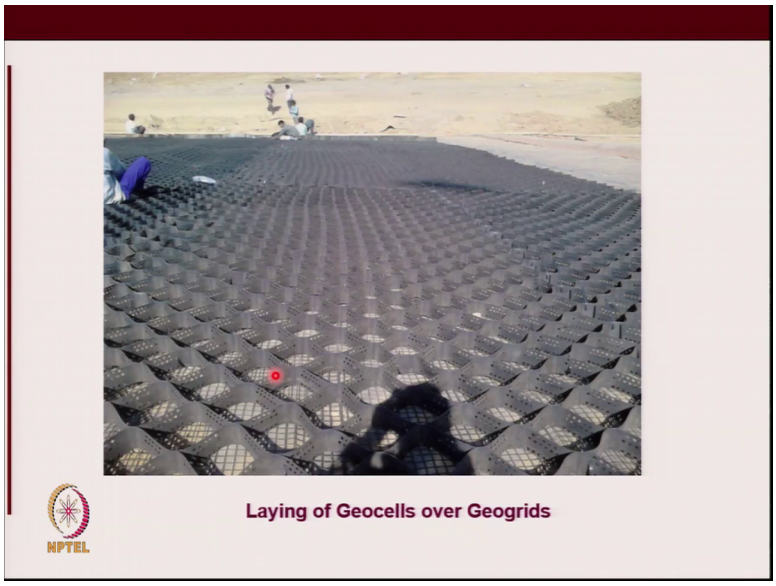
(Refer Slide Time: 35:31)

Grow some plants and creepers this is not the green look this is a at the gazebo landfill on the slope they are using paver blocks because soil was not stable.

(Refer Slide Time: 35:35)

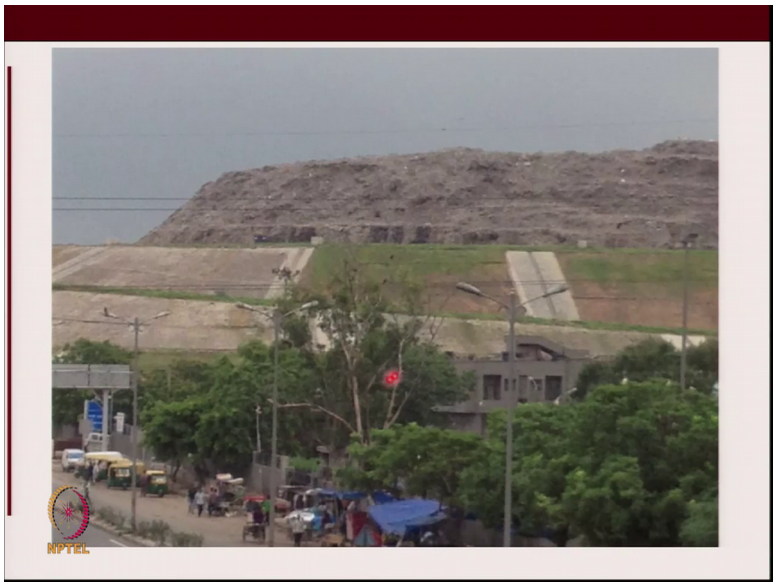


(Refer Slide Time: 35:59)



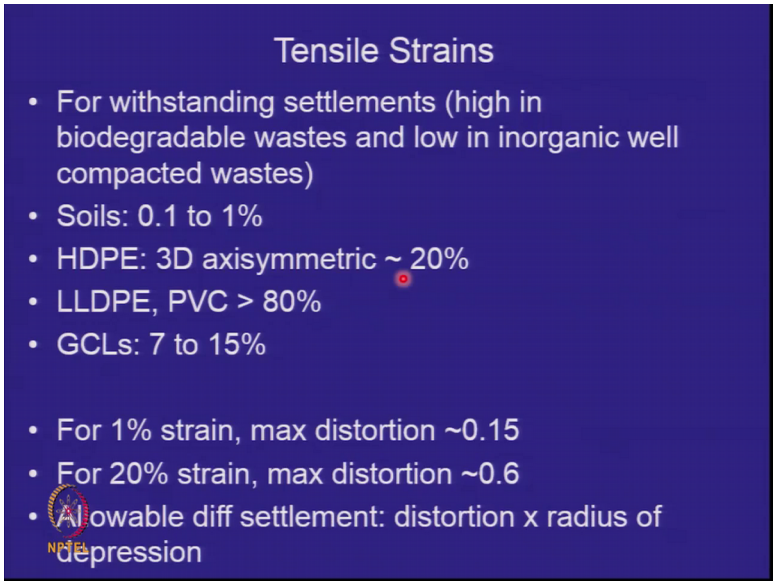
We look at it in the slope stability issue, but I just want to show you that grass in the paver blocks along the side these are Geocells, I said Geocell filled with soil; Geocells are nothing, but 6 inch high accordion arranged bands of geosynthetics.

(Refer Slide Time: 36:15)



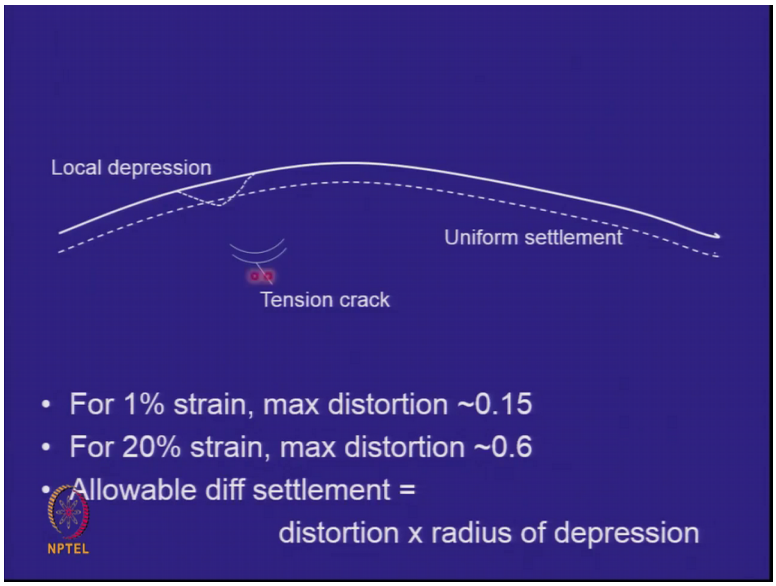
You can fill soil in it and hold it put a Geogrid you can see Geogrid at the bottom and that is the Geocells that is the rock toe and that is the finished slope and these are the drains which are taking the water down these are paver blocks these are Geocells this soil.

(Refer Slide Time: 36:29)



So, one of the things which bothers us is about settlements right and what bothers are really is if you have uniform settlement I talked about 10 percent if I am saying they are having a convex top if the settlement is uniform it does not bother us.

(Refer Slide Time: 36:36)



But the issue is if you have a local depression right if you have a local depression this is going to point up with water and please remember once you have a local depression you have a tension crack at the bottom right if it is flexible the tension crack will not form, but how flexible can you be. So, one of the indicators is in highly biodegradable wastes how much tensile strains can you can talk.

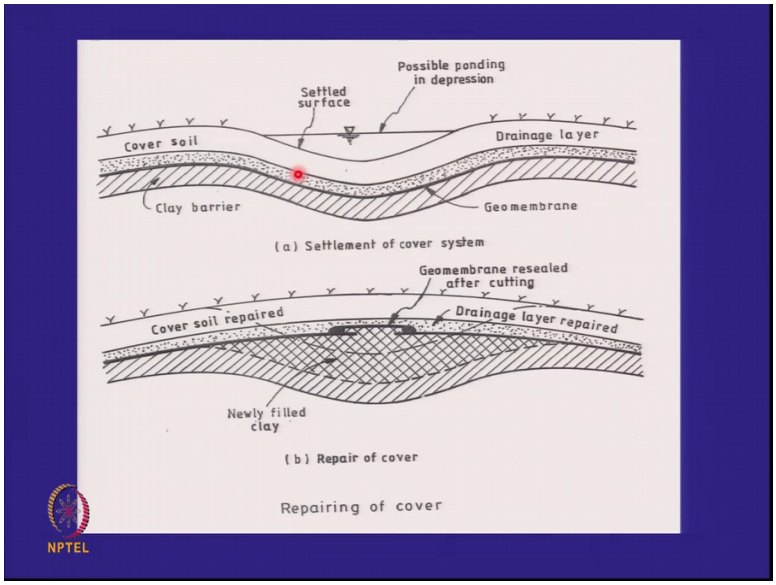
So, we say soil is flexible we said soil is flexible it can take tensile strain of about one percent HDPE, I told you last time elongation at break was how much or elongation at yield did I give you some values in the liner system yes I did 50 percent to 100 percent is what we were talking about, but that is when you pull when you pull it in one direction you will get 100 percent means that it is elongated to double its length, but this is axis symmetric in both directions because when a depression is formed tension is in this direction also and in this direction also.

So, then the extensibility is 20 percent if you are expecting more you can use LLDPE and PVC while HDPE used in the liners is because it is most resistant to chemicals LLDPE and PVC and pet are not that resistant to chemicals there are some chemicals which will affect them. So, HDPE in the liners, but if you are going to have large craters forming on your landfill then these are having 80 percent and Geosynthetic clay liner manufacturers claim that they are better than soil this is one percent they can take seven to 15 percent strains, right.

So, if I can have one percent strain then the maximum distortion that I can have is 0.15, after that soil will not work if I have 20 percent strain then the maximum distortion that I can have is 0.6; it is simple geometry allowable differential settlement is the allowed deformation into the radius of the depression. So, let us say you are expecting a depression to form here what radius would you like to choose local depression this is not the whole cover settling whole cover may be 100, 200, 500 meters wide, but a local depression may be 10 meters wide right a 10 meter wide. So, radius is 5 meters or let us say- 20 meter wide depression huge one radius is 10 meters if you have 10 meters what is the distortion which is allowed for clay 0.15 into 10 is 1.5 meter.

So, as long as the cover is settling by 1.5 meters clay will not have a tensile crack, but if it goes beyond that it will, but 20 percent is what is allowed in 20 percent is what is allowed in geomembrane HDPE. So, 6 meters deep it can take. Therefore, for tackling settlements you need to have either repair taking place see is not an issue if you are repairing it very fast which is what I am going to show you next then this depression will not form if you are having a weekly inspection.

(Refer Slide Time: 40:39)



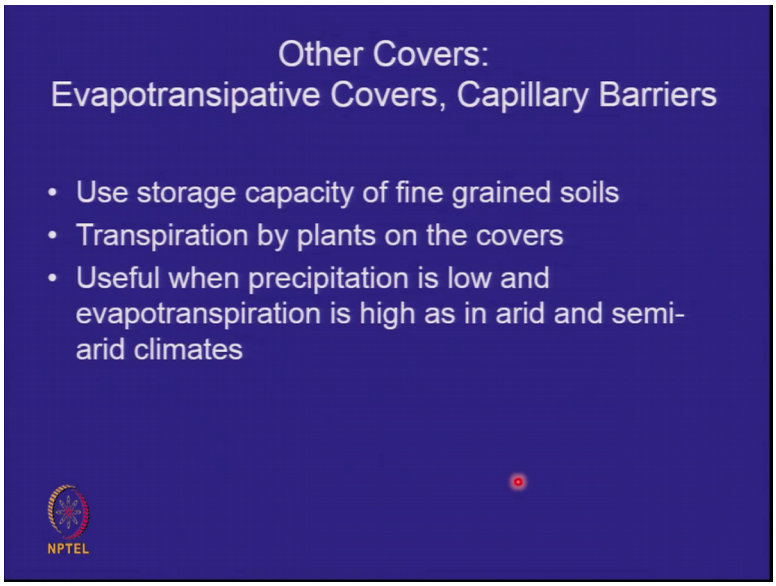
So, how do we do cover repair if a depression is formed you have got the problem is if it is stormed you can have pounding and you can have problems. So, you come back and dig this up you cut this geomembrane fill up here the soil at the bottom and put another

piece of geomembrane on top you bring it back to its convexity. So, how often you are repairing makes this depression smaller and smaller if you see it early you can repair it.

(Refer Slide Time: 41:14)

So, this is the way to repair covers. So, covers will undergo large settlements long term settlements can be of the order of 50 to 30 percent of landfill height short term movements of half to 1 meter. So, whenever you have a depression which is local see when I talk about 15; I am talking of the whole thing settling with time, but local depressions which form are typically half to 1 meter and these can cause bondage. So, regular repair is required.

(Refer Slide Time: 41:50)



So, soil can handle 0.5 to 1 meter, but soil will not handle much larger depressions I would like to conclude by talking of we have been talk about dry tome landfills we have been talking of putting elements which do not allow water to go in, but you will come across 2 terms which are used very often give Evapotranspiration covers and capillary barriers you will have covers which are different from the once we are talking of which are not yet used in the country, but are used in arid and semi arid climates and Evapotranspiration cover is one you have soil let us say I am going to have 100 mm of rain right.

So, if I can make the soil design the soil such that this 100 mm of rain never goes through it falls it runs off whatever comes inside is held at storage and then the plants give it back up you do not let the water reach the bottom. So, in arid and semi arid climates this all works on capillary action you have to use fine grained soils because they are able to hold more water typically use gravel always go through use sand also go through so silts and clays and silty clay themselves.

So, you can design relatively thick covers in which water can be held and evaporated. So, this is the new concept which is coming up requires very strict quality control and we look at a calculation for Delhi and we need pretty thick Evapotranspiration covers, but what their philosophy is that they are doing away with a geomembrane or a compacted clay barrier and they are saying we will put covers which will not allow the water to go

through, but you must have some acceptable limit of water which has to be allowed through.

So, Evapotranspirative covers and capillary barriers or systems which do not allow the water to go below the cover purely by the holding capacity the capillary action and having plants which will send it back up. So, in arid and semi arid climates evaporation may Evapotranspiration will normally be more than the precipitation which takes place over the year, but at peak time precipitation will be more than the Evapotranspiration at that time the soil should be able to hold it and your plants should be able to take out that water from the system.

So, with this we come to an end of the our discussion on covers you would have now got a fairly good idea of what the covers and liners look like as well as the alternate materials which we use one of the questions which one would like to reflect upon is if I we are talking of Geocomposite liners at the top sorry Geocomposite drainage systems at the top in the cover can we also have Geocomposites for drainage in the liner system because on the liner system also there is a gravel and sand drainage layer Leachate collection layer. If I can have water coming from rain into the top of the cover and replace the sand with the Geocomposite which allows in-plane flow of water can I use it in the Leachate collection layer and the answer is no because Geocomposites can become clogged by the Leachate which comes down not by particulate matter, but by the organic growth of various kinds of organisms in the Leachate.

Whereas, the sand and gravel systems are one foot thick. So, they have pipes in it which you can back flush the systems. So, Geocomposites are not considered for Leachate collection layers at the bottom, but they are considered for the drainage layers and the gas collection layers at the top.

So, any questions you that you might have something which bothers you or you have a better thought about how we can do these covers so many layers something by which you can reduce. Anyway, think about it and we will discuss it in the next class.