Geosynthetics and ReinForced Soil Structures
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Lecture - 38
Introduction to Geosynthetics in Landfills

Very good morning students, let me give you a very brief introduction to the landfills in this lecture.

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Let us first see what is the landfill? So, landfill is nothing but any engineered depression that is purposely constructed within the ground to dispose of different type of wastes. The industrial society has become a waste generating society, we generate lot of waste in the process of our daily activates. In the process of lot of manufacturing of different products for our comforts and where do we dispose of all these waste. Some of them there could be highly toxic and if you in this permanently dispose them of in the open, they might contaminate the ground water or the environment. So, we should prevent them from contaminating the surrounding environment for our own benefit and for our own longevity, these landfills coming handy.

See one very simple example, that I can give for the need for landfill is most of the Indian cities, we do not have any place to dump the garbage like whereever we see we

dump them. Whenever we pass by those areas, we see this and it is an ugly scene to see the garbage spread all over animals and then the birds that are feasting on the waste. So, the landfill is an opportunity for us to safely dispose of the waste to prevent this type of discomfort to the people.

These landfills are constructed using some impermeable lining material, so any leachate that is produced is prevented from migrating into the ground leachate is nothing but a solution that is produced, when water is pass through any material especially the material of the waste is of our interest. This waste could contain some chemical waste or some toxic waste or some other biological products.

If any water flows through them, it absorbs those materials and it becomes that itself might becomes toxic and so we should prevent that leach ate form migrating into the ground by providing some abstraction. These landfills are constructed below the ground level mostly and after they are fully filled up with garbage or some chemical waste and other products. We need to give a cap and that is called as covering up after they are completely filled with the waste. In this lecture, I will give you a brief introduction of the different components of these landfills and how they are built, and why they are built, and so on.

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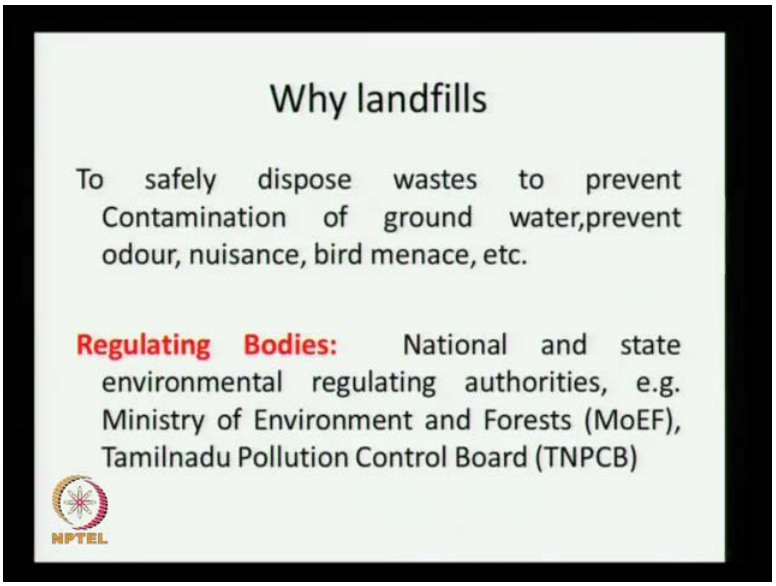

Why landfills very simple, because we need a space to dispose of our waste and not just simply dispose, but safely dispose waste, these landfills are required. These landfills are

required to prevent contamination of the ground water to prevent order nuisance, of the birds and animals are feasting on this garbage that we throw. We also need to make sure that the environment is not polluted, the air is not polluted or the surroundings are not polluted and the construction of all these landfills is regulated by several bodies.

For example, at the national level we have some controlling authority and also at the state level there are some state regulating authorities of the national level in India. We have the ministry of the environment and forest is in short MOEF and in Tamil Nadu, there is a Tamil Nadu pollution control board of the TNPCB. They provide us the guidelines on how to dispose of the waste and where to dispose of and how to construct these landfills and so on.

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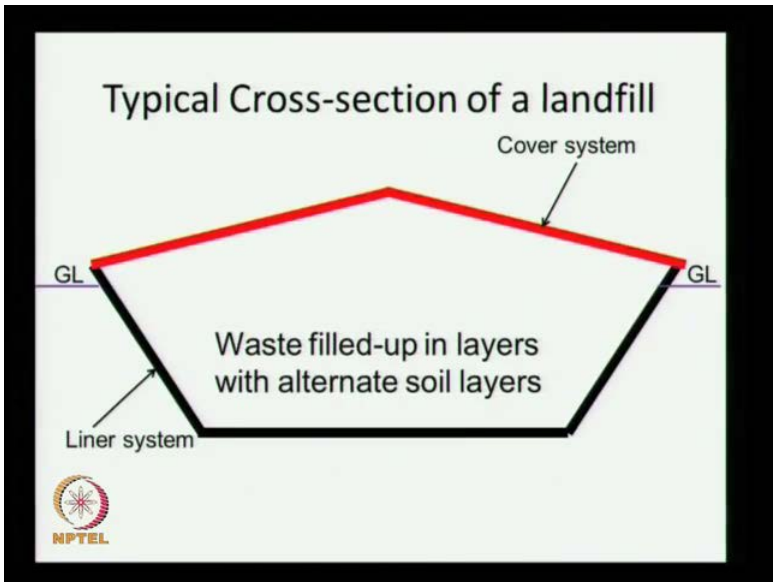

A typical transaction of landfills is like this, it is a highly simplified pictorial representation it does not include all the components, but that we will see later on. Let us say that, we have a ground level somewhere here we execute we make a depression. In this picture, I have just shown one single slope, but depending on the depth of execution we could have multiple slopes like with several burns, so that it is easy for the transport vehicle to move on these slopes.

We deposit the waste that is collected from different localities within the city or from different factories and we surface this garbage trucks going on the roads very frequently. All these garbage, that is collected from different households and different localities is

brought to this type of facilities. They are dumped and then they are compacted, because when if you just simply dump this waste they occupy large volume and if we compact them you can you can compact them or you can store them in a more compact form. Usually, this waste is dumped compacted and periodically we put a layer of soil, because the soil is the one that provides the bacterial logical environment to eat up this garbage or the waste and so that there is some biological degradation over a period of time.

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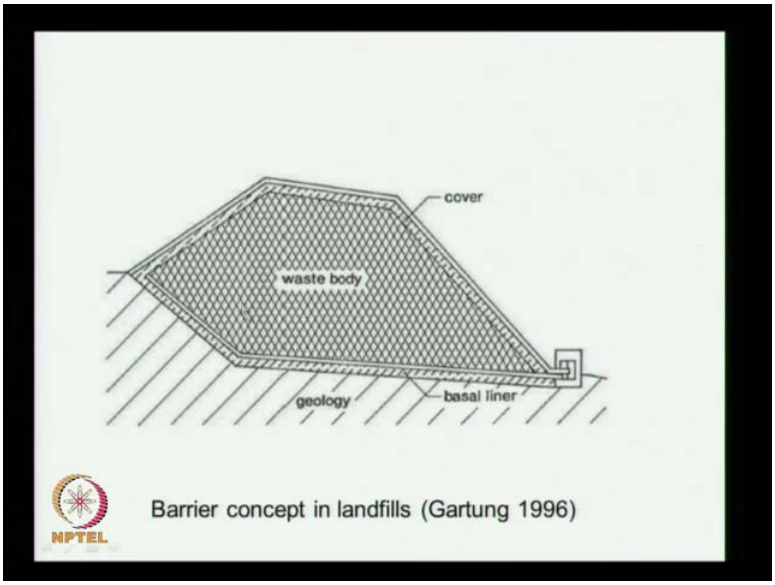

So, the typical construction is shown here, we have the waste body and we have the barrier and a liner system and the geological medium of the original soil here. Above the waste body, we need a cover system to prevent the odors from escaping into the environment or we need a system to collect all the gases that are produced, and safely dispose them off. Here, I will show you in a moment all the components of the landfills.

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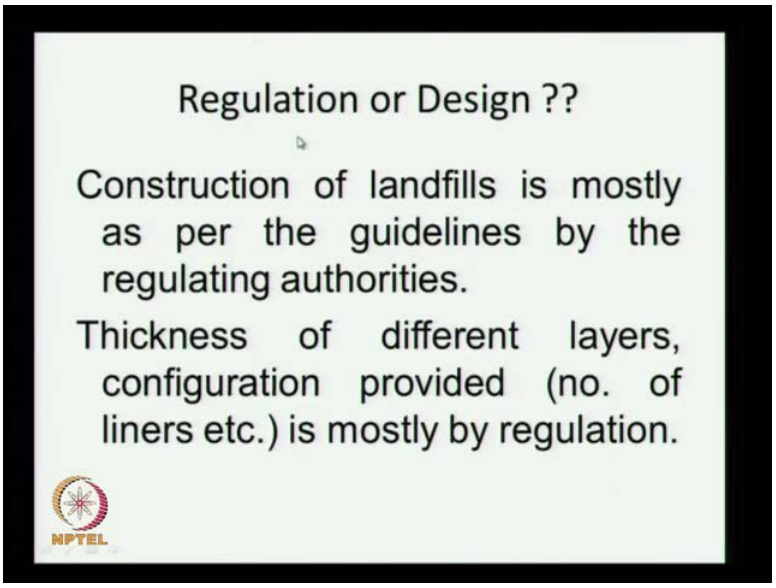

So, at these regulated or designed places, the landfills are mostly by regulation and continue of the landfills is mostly as per the guidelines given by regulating authorities, and that is the thickness of different layers the liner materials. The filter materials or the drainage materials are mostly done by regulating authorities, because it is easier to give general generic guidelines to be flowed by different type of industries. Different municipalities based on the size of the population and other things rather than leaving it to some designers, and what we design is mostly the slopes and then the materials that we that we utilize and so on.

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There are different types of landfills or the categories of landfills depending on what we store them, the simplest one is the mineral waste or the construction debris because the construction debris could be a lot. Whenever we demolish a building, we get lot of debris and we need a space to store that material and usually this construction debris is in earth and does not produce any toxic leach ate or anything. We do not really require a large engineered landfills and then the other category is the municipal solid waste is actually it may have a mix up waste products.

This could some biologically degradable materials like the vegetable matter and other things, and it could also contain some chemical waste because we use a lot of chemicals as the sun the cleaning agents and in our households. Our household garbage also includes that product and the municipal solid waste is slightly more complicated to handle than the construction debris.

So, we need the some guidelines for on how to store the municipal solid waste and then the third category are the landfills that are required to store hazardous waste. These hazardous waste are those that are produced in the chemical industry and say the nuclear industry, and so on and how to handle them. How to store them is also a big technical matter, that needs to discussed and regulated.

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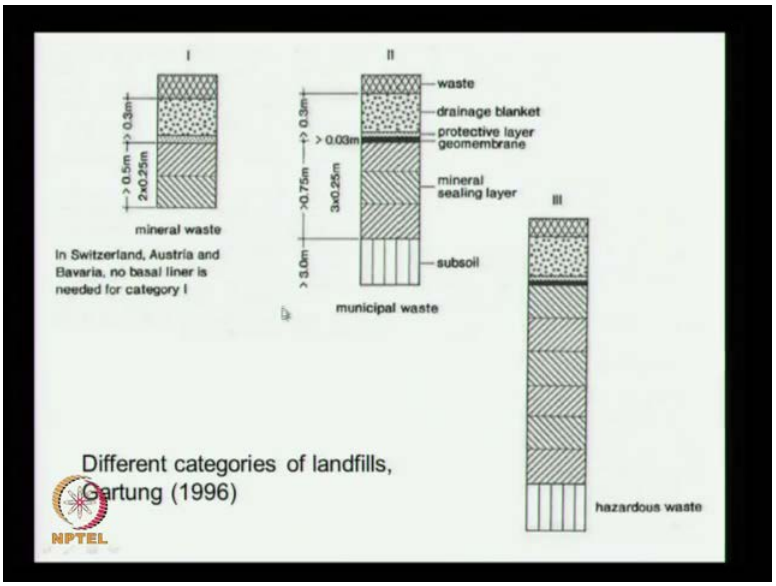

Here, we see the different cross section that is given for the three categories: first one is the mineral waste and these are all, the different layers are actually it is not very

complicated because cause the mineral waste does not produce much of a leachate. The municipal solid waste could produce some leachate, that may be toxic to some extent depending on the amount of chemicals that are through nil. Along with our domestic waste, this contains lot of number of layers that I will explain a bit later on. The hazardous waste landfill contains more number of layers because we need more protection to prevent the leachate from escaping into the surrounding soils cause that also, I will explain a bit later on.

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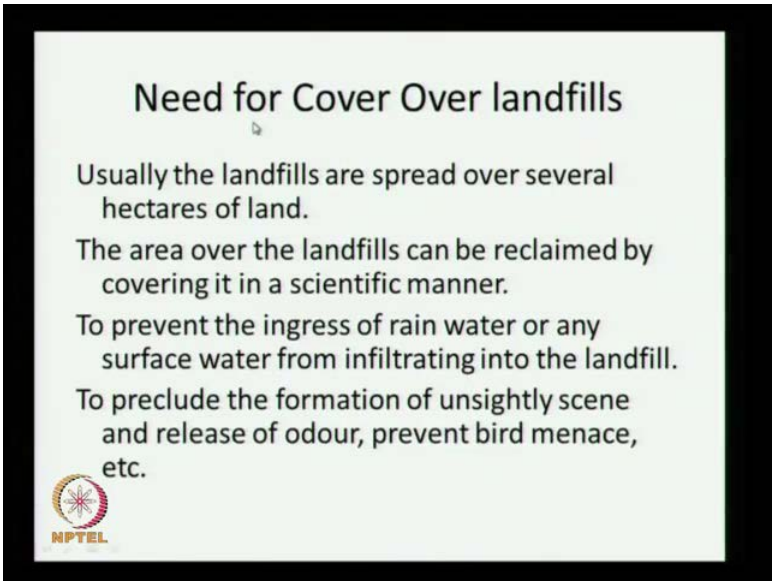

How the landfills they cover is something that we place on a landfill because of several reasons. Usually, these landfills are spread over several hectares of land hundreds and thousands of hectares. That much area is required, so that we can continuously dump the waste from a large municipality or a city for continuous period of time say about 10 to 15 years. We dump the waste and of some point this whole thing is filed up and what do we do with that land, we cannot simply leave it like that because we may like to use that land for something else for recreational purposes. Also, we should make sure that the water does not enter this landfill and for that purpose.

We need to provide a cover and the area that we have in the landfills activation be reclaimed by converting it with some scientific manner, so that we can reuse that land for building houses are for building parks schools and so on. We need to also prevent the ingress of rain water or the surface water from infiltrating into the landfill because once

the water enters, it makes the leachate and that leachate has a capacity to flow. Whenever we have water at high pressure, it like wants to flow and that flow needs to be prevented and of course, to preclude the formation of unsightly seen and release of bad odors or the prevent the bird and animal menace we need the covers.

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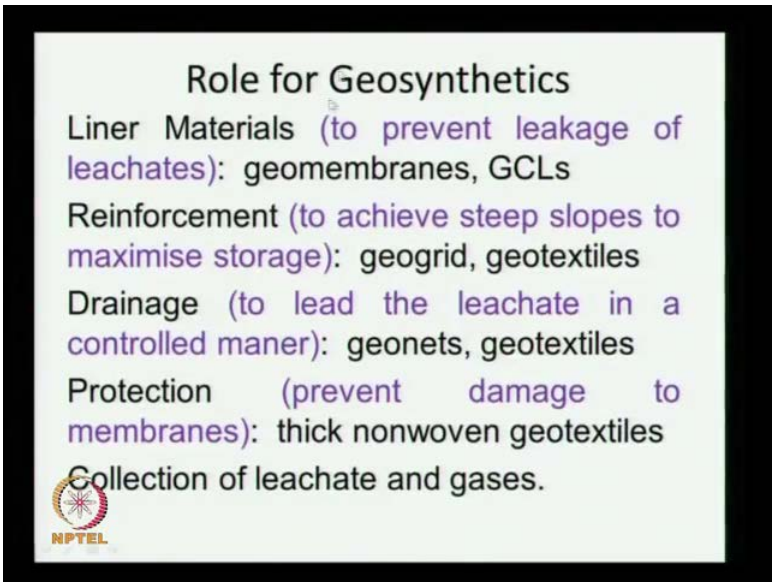

What is the role for geosynthetics? These landfills is actually there is a very big role that the geosynthetics can play and some of the items where we need to provide geosynthetics are listed, here as geosynthetics can be used as liner materials. A liner material is a material that prevents the leakage of leachates. The liner materials are geomembranes and the GCL's, these are two types of geosynthetic material that are highly impermeable and as a reinforcement also we can use the geosynthetics to achieve steep slopes so that we can maximize the storage. If you provide a shallow slope, we need a very large land to crate landfills. If you are able to provide a steep slope, we can within a small area we can maximize our storage space.

To the construct the very steep slope, we need to provide some reinforcemental airs in the form of geogrids or geotextile layers. Thereby we can maximize our storage space for storing the waste and as drainage layer. We need some drainage layers to collect or the surface run off or to collect the leachate and lead it safely to some collection points, and some of the drainage materials that that we have are the goenets and the geotextiles the geonets.

We have seen that they are very thick related relative to the geogrids and they have the ribs. The other members in 2 different planes so that you create a large void through which the water can easily flow or the geotextiles are also excellent drainage materials. As we have seen earlier, we can safely lead the leachate or the water by flow through the geotextiles.

We also require some protection to prevent damage to our membranes are the geomembranes that we provide these geomembranes are provide over very large areas. We need to provide some protection on top of the geomembranes so that we do not punch any holes or damage during the process of construction and the compaction. Finally, as we need some collection agents for collecting the leachate and gases that are produced. For that also, we require different types of geosynthetics, the geopipes or the perforated pipes lined with geotextile or the geonets geomembranes, sorry the geotextile and so on.

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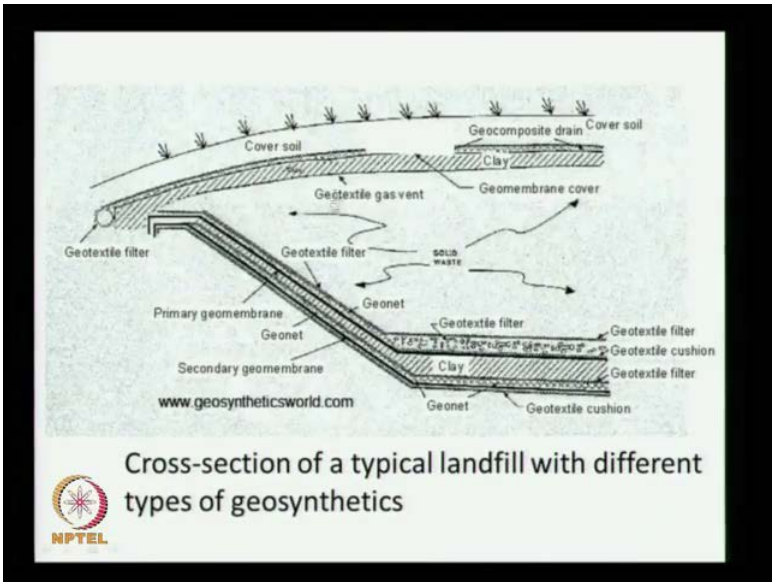

In this picture, we see a typical transaction of a landfill that has both liner and also has a cover. This particular one is downloaded from this web site and here, we see a typical landfill with cover and the cover is provided on top of this the waste. It consist of a cover soil so that we can grow some vegetation and then we could have a geocomposite drain, so that any surface water that enters it can be lead safely into some collection points.

Then, we may have some geogrid layers as reinforcement because that waste that is dumped into landfill although it is well compacted it can still undergoes some compression during the course time because of the biological leakage of the organic waste. Gradually, the waste volume might reduced that allows the surface to get compressed in order to prevent this cover from cracking up we may need to provide some geogrid reinforcement. Finally, we have a clay barrier we and we may have a geomembarene also to as a impermeable membrane to prevent any water from leaking into the into this landfill.

Then, within the landfill we may have a geotextile filter just below the waste and then have we could have a drainage layer and then below the drainage layer, we may have a primary geomembrane. Then we could have another drainage layer and a geonet and then secondary membrane and so on. Then periodically, we will have these collection points along the length and width of the landfill.

The purpose of these collection points is to collect any leachate or the liquid waste that is flowing through the landfill and once it is collected here, this collection pipes they lead the all the fluid into some common point where it is treated and then discharged back into the environment. It is collected or stored in some other place. So, we see that we can use the geotextile the geosynthetics in several manners, we can have a geotextile or a geomembrane, and we could have a geonet or geopipe. Then we can also have GCL, that is the geo geocomposite liner, the GCL consists of both geotextile and then a thin layer of highly expansive clay like detonate slurry, detonate powder.

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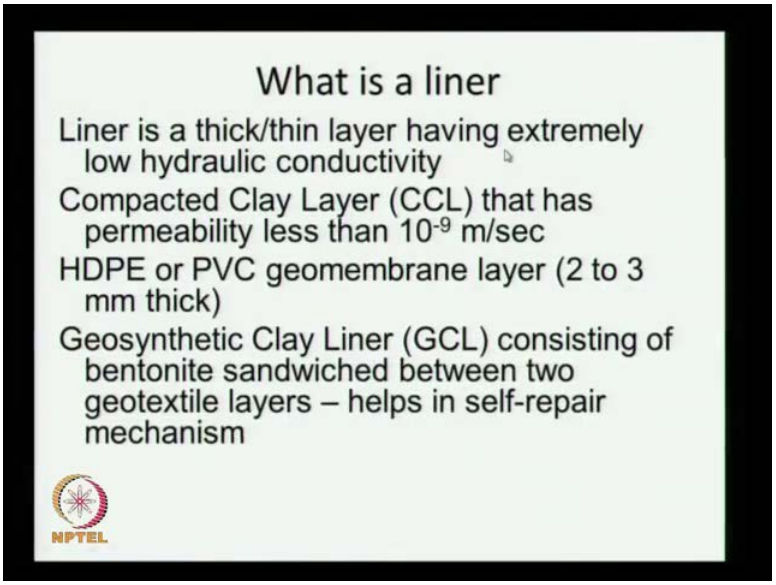

So, liner is a very important component of any landfill a liner is a thick layer that is if it is a clay layer it is thick and a thin layer, if it is a membrane or a geomembrane. The gallium usually about two and half millimeters thick or maximum 3 millimeters thick, and clay layer could be anywhere from half a meter to 1 meter thick compacted clay layer. This compacted clay layer should have a permeable to less than 10 to the power of minus 9 meters per second is highly impermeable.

The geomembranes, it could be made of either HDPE or PVC and usually they can be of anywhere from 2 to 3 millimeters thick or if you are providing multiple geomembrane layers one or two of them could be thinner layers thinner layers is compared to more thicker layers at the bottom. The geosynthetics clay layer clay liner is another good example of a liner material that consist of a bentonite powder sandwich between to the geotextile layers. This helps in self repair mechanism, that is the GCL is provided a below a compacted clay liner and a membrane and below that we provide this GCL.

If there is any leakage through the geomembrane that fluid comes in contact with the GCL. Once this fluid ingress into this a bentonite slurry or bentoite powder, it expands in volume cause we know that bentonite is a highly expansive clay. It has a very high free soil index and in the process of expanding it presses back the geomembrane into the clay layer that is closing the opening whatever is created in the geomembrane.

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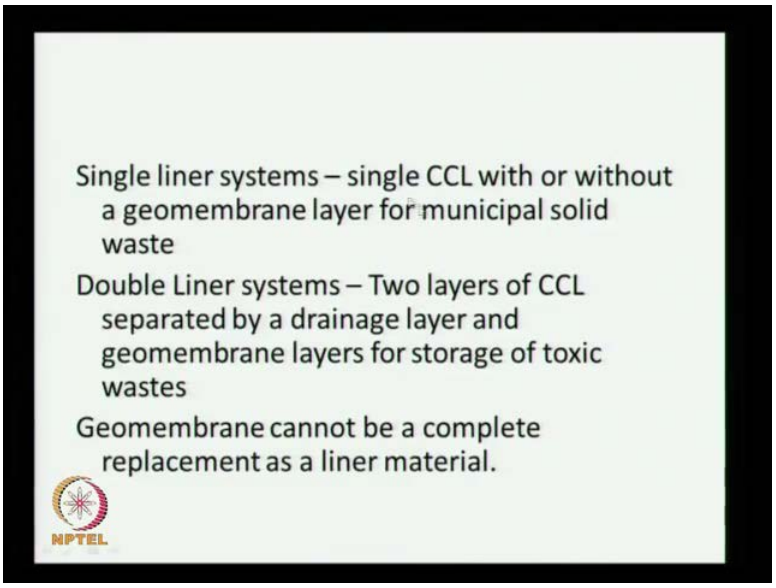

There are different lining systems, we have single liner system the single compacted clay liner with or without a gallium layer mainly for municipal solid waste or first store in the mineral waste like construction debris and so on. We can have a double liner system, it is with two line, two layers of CCL separated by drainage layer and a geomembrane layers for mainly for storage of highly toxic waste. You may be wondering, if the gallium is highly impermeable, why not we completely gated of the clay liner. We cannot do that because the geomembrane is very thin and if there is any puncher in the geomembrane the liquid can simply flow through, whereas the clay liners they are thick.

Then the difference between the clay soil and the geomembrane the clay soil, because it is very thick and it can support some organic matter or micro organism that can interact with the waste product. That may lead to biological degradation of the waste cause the membrane cannot support any micro organism. We cannot hope to achieve any biological degradation by just simply putting one layer of geomembrane.

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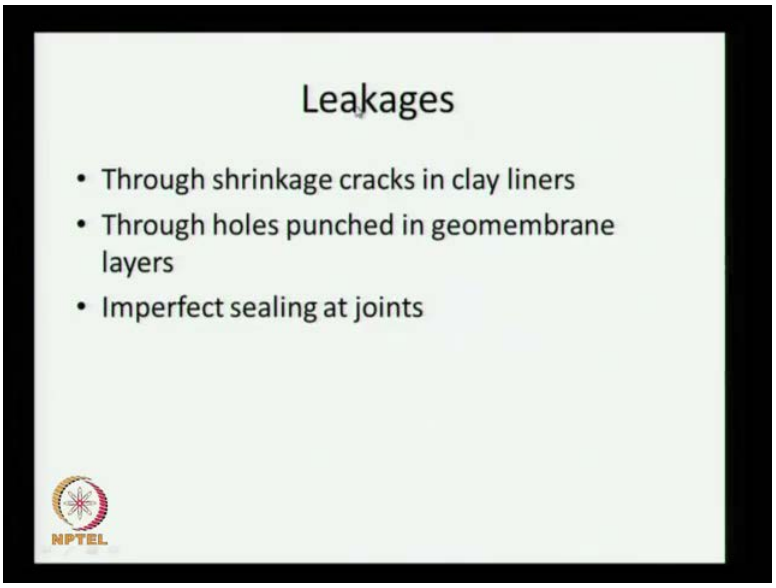

So, after the construction of these of these landfills will there be any leakages there could some leakages mainly because there could be some shrinkage cracks that are formed in the clay liners, because we know that if the moisture content of the clay soils decreases. It shrinks in volume that may lead to some shrinkage cracks through which water activation flow or we can have the holes punched in the geomembranes during the construction process, because in the process of construction we lay the geomembrane on top of that.

We dump the clay soil and do the compaction and sometimes we may have large size aggregates mixed with the clay soil. That could just simply punch holes into the geomembrane. We may have imperfect sealing at the joints cause wherever there is a joint the geomembrane, we do some ultrasonic welding to weld to join the membranes.

There could some leakage through these joints and there are some systems to detect the leakage by some electrical conductivity methods. Then whenever there is a leakage the information is send to some control point, so that some remedial action activation be taken or we can have a collection system to collect all the leakage that comes through these through these imperfections.

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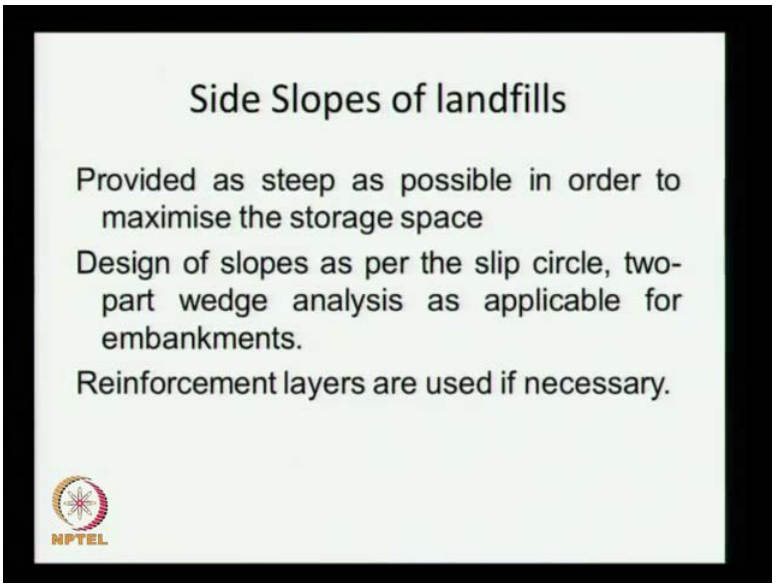

How do we design the side slope of landfills, so our object is to provide a steep side slope as possible, so that we can optimize the storage space that means that we need to do some design. The design of the side slopes is as per our earlier studied slip circle methods or the two part wedge analysis as applicable for embankments. We can do a similar analysis and come out with some designs and if necessary we can provide some reinforcement layers in the form of either geogrid or a geotextile to make these slopes as steep as possible.

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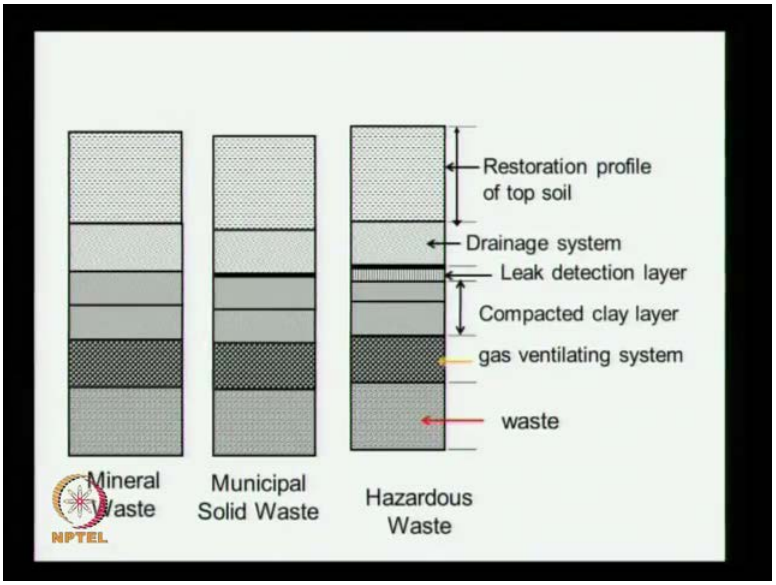

This picture shows different types of lining systems that we can have for the mineral waste for municipal solid waste and hazardous waste is actually the main components of all these landfills, we need a drainage system. We need a membrane and we need a compacted clay liner it acts as barrier. Sometimes, we can have a leak detection system especially when we are storing highly toxic waste, we need to detect any leakage, so that we can take some remedial action.

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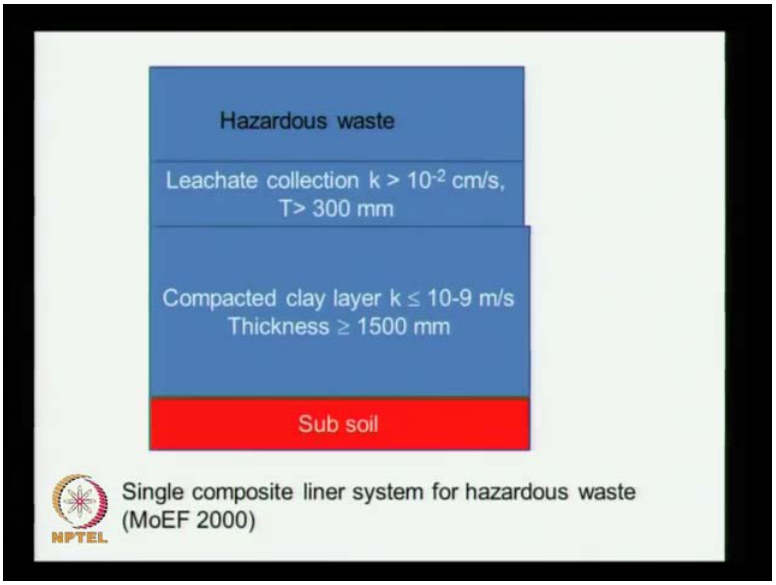

Here, we see a cross section as recommended by ministry of environment and forest this is the single composite liner system we can have a hazardous waste. We can have a leachate collection adsorbing medium this thickness should be more than 300 millimeters and the permeability of this soil should be at least 0.1 centimeters per second. Then below this we can have a compacted clay liner of at least 1.5 meters thick. Permeability should be less than 10 to power of minus 9 meters per second, so that the water or any leachate does not flow through and below this we have the sub soil.

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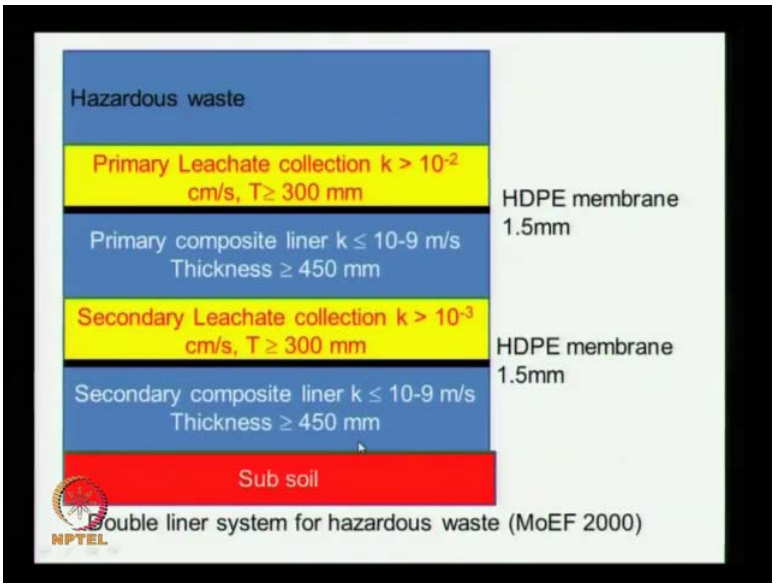

Here, is the cross section of a double liner system we can have a hazardous waste. We may have a primary leachate collection system or a drainage layer having a permeability greater than 10 to power of minus 2 centimeters per second and the thickness greater than 300 millimeters. Then we can have a composite liner the primary composite liner that is the compacted clay liner of having permeability less than 10 to power of minus 9 meters per second and thickness greater than 450 millimeters. In between we may have an HDPE geomembrane of thickness of at least 1.5 millimeters.

Then we can have a secondary composite liner that is the compacted clay liner then once again HDPE membrane of 1.5 millimeters. In the second in the single lining system also we can have a geomembrane below the compacted clay liner depending on the requirements. Here, we see that the single liner system the thickness of this liner is 1.5 meters, whereas in the double lining system because we have two geomembranes.

We have two different clay liners the total thickness of the clay liner is less than 900 millimeters as oppose to 1.5 meters in the single lining system. The double lining system is usually provided in the case of hazardous waste because it is the consequence of any leakage through the hazardous waste landfill is more caviar. To increase or to improve our reliability of the designs we provide the double lining systems.

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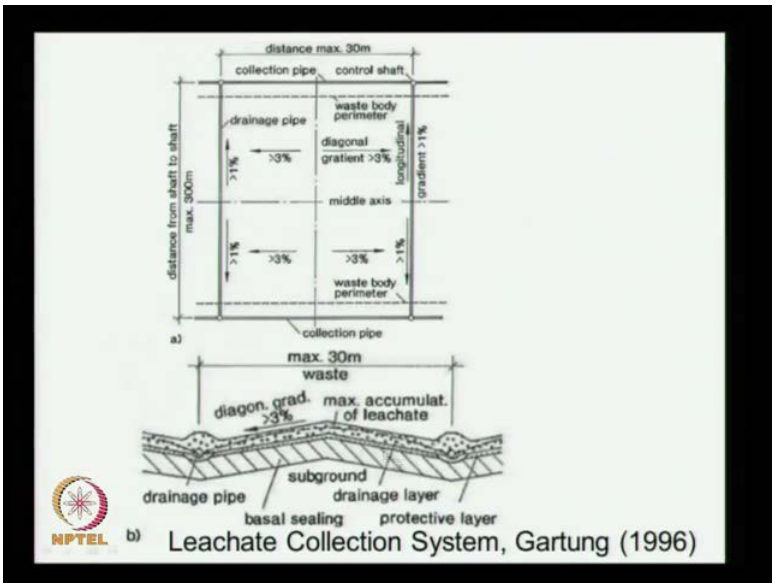

This picture shows a typical collection system the entire landfill, we give some gradients at the bottom and at the environment bottom point of all these places, we provide some collection pipes like this is actually, this is the plan view periodical. We have this perforated pipes running along the length and width of the landfill and the cross section itself we have some gradient of at least 3 percent. So, that acidity leachate that comes through flows through the drainage medium and it get collected in this drainage pipes and these drainage pipes are nothing but perforated plastic pipes.

Sometimes, we may give a covering of a geotextiles, so that they do not get clogged or if not geotextile covering. They are given some covering of a filter medium in the form of stones and pebbles and the leachate because of the gradient that is provided. It flows into this collection points and because these drainage pipes are provided along the length and width periodically, we can drain this into some common points for collecting the leachate. Once this leachate is collected, it is treated and disposed off safely.

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Here, we see a picture of the leachate collection channel is actually we give some gradient and then here we will have our leachate collection pipe.

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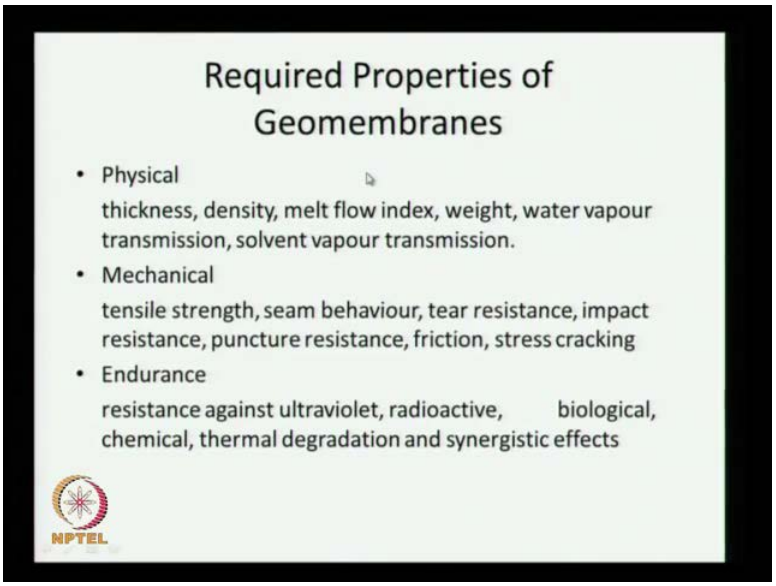

What, are the requirements for the geomembrane the physical properties that are required. It should have sufficient thickness and it should have some sufficient density, and a high melt floe index and it should have the weight or the density and should have a very low water vapor transmission. Then vapor solvent vapor transmission, so that the liquid or vapor waste is contained within the landfill and it should have some mechanical

properties like the tensile strength. It should have good seam strength and the tear resistance impact resistance, and the puncture resistance. It should have a good surface friction, so that our slope that is constructed is stable and it should have a good stress tracking resistance.

It should also have good endurance to resist the ultraviolet radiation and it should be stable against biological, and chemical actions, and the thermal degradation and because the temperatures within the landfills could be very high because some of the waste. When they are biological degrading, they can produce lot of heat and they can produce methane gas and the membrane that is placed, it should be stable against all this chemicals.

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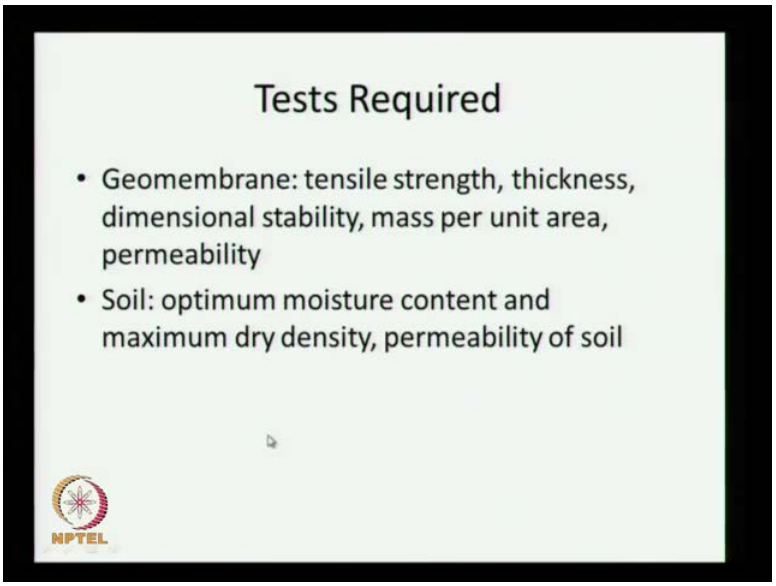

Some, of the tests that are required on the geomembrane are the tensile strength thickness dimensional stability, especially at high temperatures then the mass per unit area. The permeability of water and gases and on the soil we require optimum moisture content and a maximum dry density, the permeability of the soil and of course, the other properties like the grain size distribution and so on.

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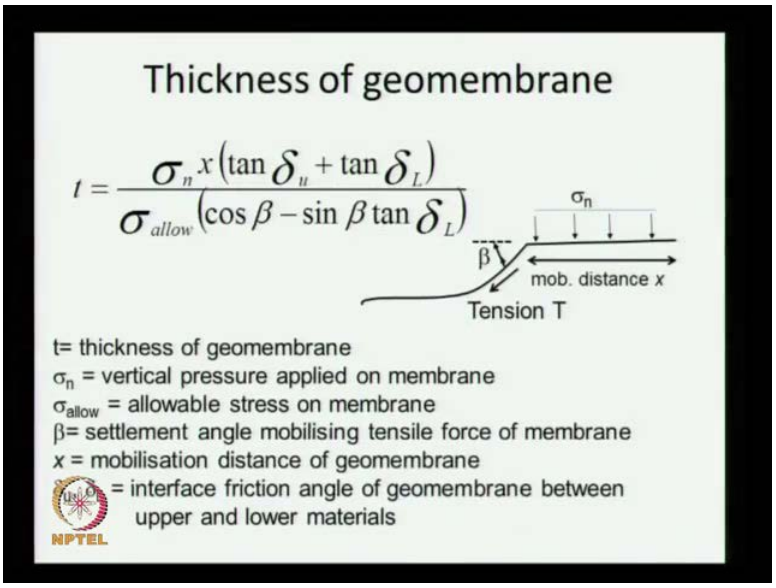

There are several empirical relations given for determining the thickness of the geomembrane. The side slope stability and one equation that I have taken from the corners text book is given like this the thickness of the geomembrane is related to the allowable stress in the geomembrane. This stresses that are transferred the t is sigma n x multiplied by tan delta u plus tan delta L divided by sigma allowable times cosine beta minus sin beta tan delta L, where x is the mobilized distance actually this is nothing but the accurate distance that we have seen in the case of embankments.

Then in the case of retaining walls and the sigma n is the over burden pressure and tan delta u and tan delta L, basically the frictional components that are developed on the above the geomembrane. Below the geomembrane and sigma allowable is the allowable stress on the membrane that we can get from doing the dumbbell tensile strength test on the geomembranes beta is the settlement angle during the deformations. So, this is one empirical equation that we can use for determining the thickness of the geomembrane. Similarly, there are so many other relations that can be found in any good text book.

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I will very briefly explain the construction of the one of the first landfills in India, this picture that you are seeing is the landfill that was constructed at the Hindustan Zinc factory in Visakhapatnam. This is to store the zerosite waste that was produced as part of the zinc smelting process and this particular factory has been in operation right form 1950s. So, they have accumulated lot of zerosite which is a highly toxic waste and that needs to be safely disposed off.

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The zerosite waste was dumped at the site for several years for almost three to four decades. The granules of the zerosite waste themselves are used for construction purpose because this particular landfill is very different from the other landfills this is constructed entirely above the ground level, because of the geological conditions. It is not easy to execute in this rocket array, so it was decide to construct the landfill above the ground level and this entire embankment was built using the granules the zerosite granules mix with soil.

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Here, we see the construction of this of this embankment using the some geogrids.

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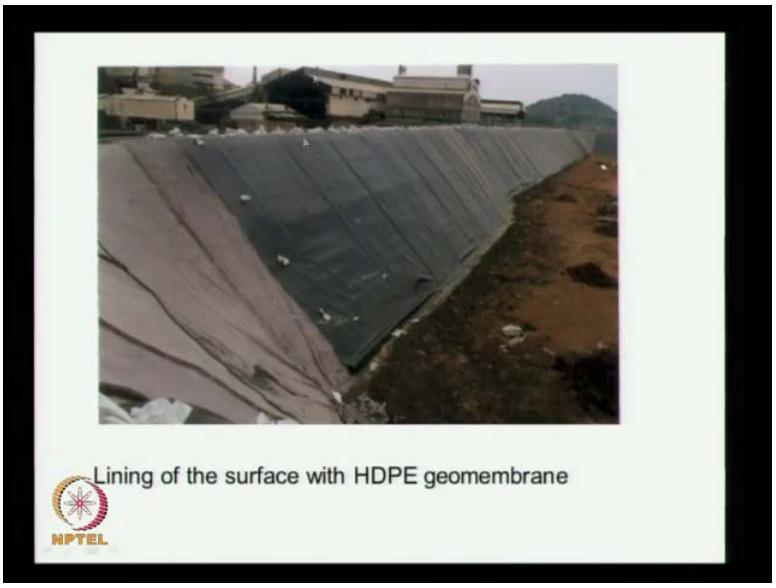

Here, we see the picture of the geomembrane that is laid on top of this of the slope that is constructed.

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Here, you see another picture of these this spreading of the geomembranes and you see that all these joints they are given along the length of the slope, and not across the length across the slope because the gravity force is acting down. If we provide a joint along this in this direction, it is subjected to lot of tensile force and it might rupture in the process of the service life.

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Here, we see this geomembranes and these geomembranes they should be at least 5 meters long, so that the requirement for the joints is lesser.

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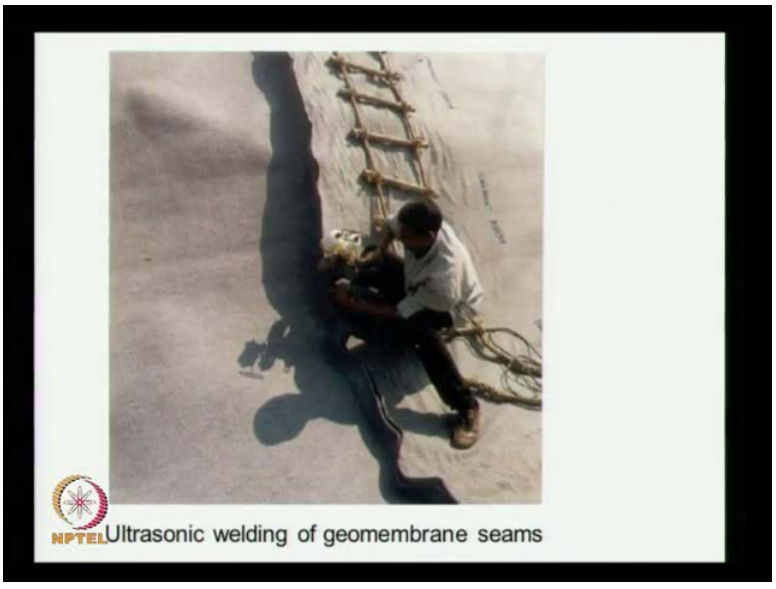

Here, we see the ultrasonic welding of the joint the joints at the geomembrane over lap locations, whatever joint that is produced.

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It should be a tested by some suitable means and here we see this this person doing the leak testing by blowing some air or the sop solution. There is an ASTM requirement that any pressure that is applied, it should be maintain a constant for certain duration of time and if it is not so then the seam has to be redone.

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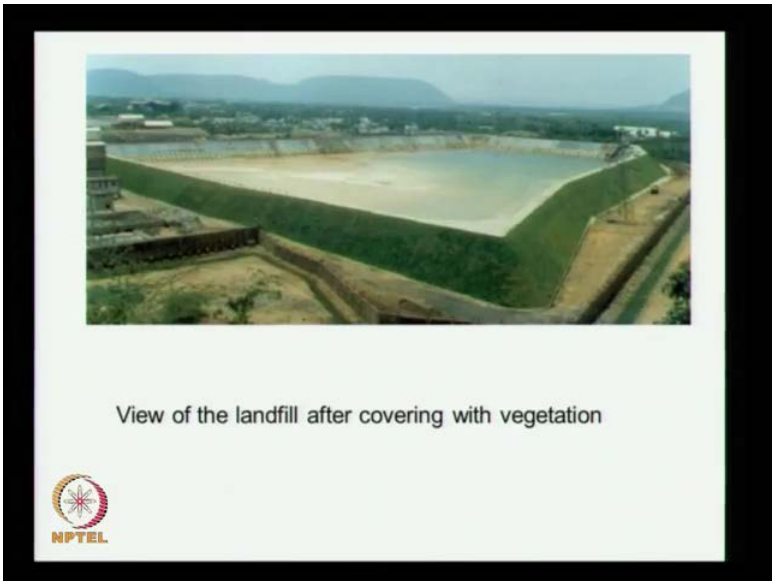

The view of the same landfill, after covering with vegetation, now this particular landfill was built in the year about 2002. Now, this entire landfill is full of zerosite waste and

they are even capping this and even the capping process might have been finished by time.

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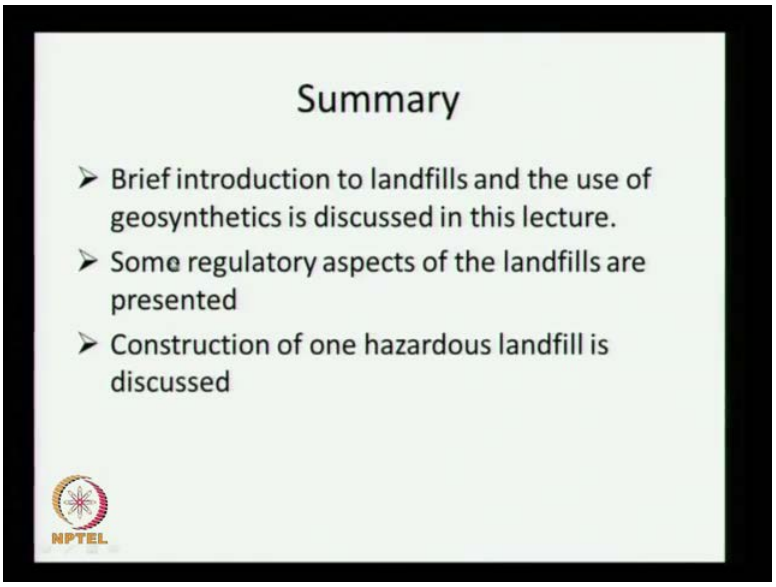

So, just summarize in this lecture we have seen a brief introduction to the landfills the need for the landfill and some regulatory aspect of the landfills. The construction of one hazardous landfill is briefly discussed and I would like to acknowledge the supports that have given that have gotten from several people.

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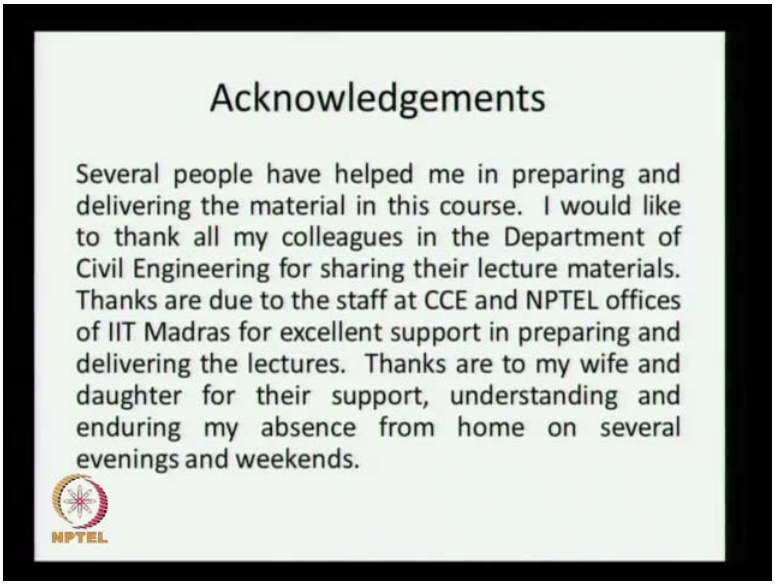

I would like to thank all my colleagues in the department of civil engineering at IIT Madras for sharing some of their lecture materials with me. I want to thank this staff at the CCE and NPTEL offices for excellent support that they have given in preparing the lecture materials and also for delivering the lectures and for recording, and for editing and so on. The last but not the least wants to thank my wife and daughter for their enormous support and understanding, because I was away from home for several days together preparing these lecture materials. They have understood and supported me all through this process, I want to thank all of them. Finally, thank you also and if you have any questions you can send an email to me.

Thank you very much.