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

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Lecture - 10
Liners for Landfills - Part 1

Good day and welcome to this class in which we will be focusing on liners for landfills. If you recall, last time we discussed a lot of planning of landfills, and today we will focus one of the components which we have to design and that is the liner at the bottom of a landfill which has to ensure that the Leachate does not percolate into the ground before we do that; let us do a quick recap.

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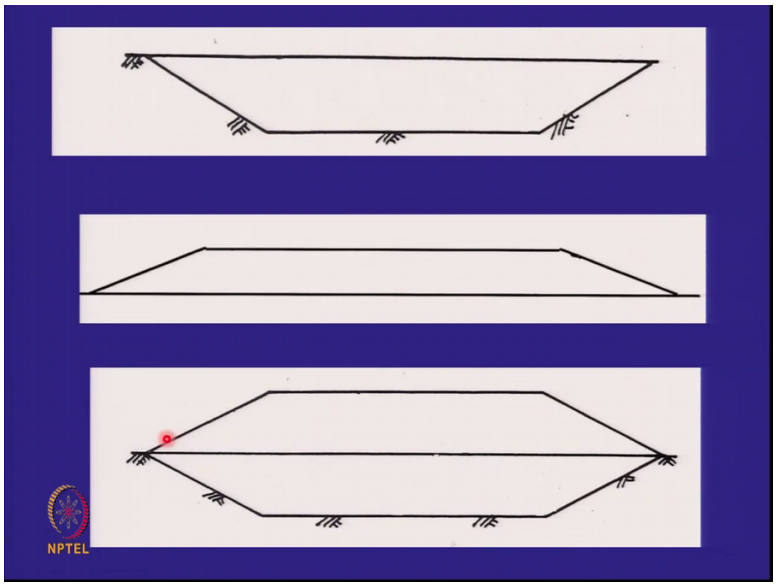

And last time as I said we were discussing planning of landfills and I would like to very briefly look at this aspect of shape of landfills I had shown you a below ground landfill and above ground landfill and a combination of the 2 and these are what are adopted on flat ground if you have if you have a ground which is not sloping or not a low lying area not a valley then your landfill looks like this or this or this.

The important point I want to make which I perhaps did not make last time was the; these are vertically exaggerated diagrams please understand this is the widths of the landfill. So, this can be very large and this is the depth this is limited as I told you typically this will be seven to eight meters in unsupported excavation if the water table is deep below, but this width can be large and for municipal solid waste landfills it can be several hundred meters or it can be a kilometer or 2 in hazardous waste landfills which are smaller which are smaller than municipal solid waste landfills this dimension can be a few hundred meters.

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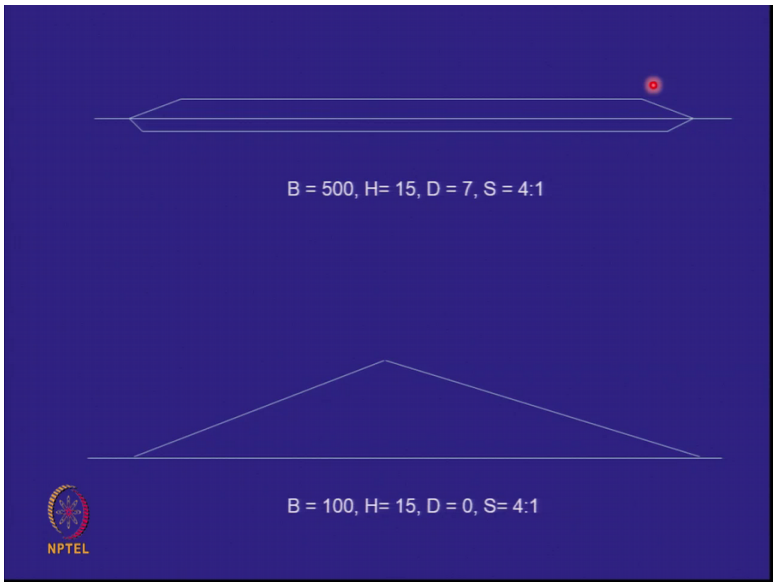

So, if I want to look at this in the correct dimensional perspective I come here. So, I just taken the scale that this is about 500 meters long and I said typically the height will be restricted to 15 meters. So, that is 15 meters and here the depth has been restricted to seven meters. So, these are thin spread out waste repositories on the surface of the ground when you have a valley then there will be high and when you have a side slope then also they can the dimensions will be significant and height, but typically on flat ground they are thin elements.

Now, here I have got B equal to 500 meters B means the a width and if you look at its suppose I own 500 meter wide land which has got a width of 500 meters I actually own everything beneath that boundary and I own everything above the boundary or is it not. So, I do not know what are the laws, if I have a plot of land do I own everything under the plot and everything above it no. So, somebody said I do not why not who owns what is below my ground. So, there is soil beneath my feet who owns that soil if I wanted to bid build an underground building which was 5 stores is deep can I build it.

So, unless there is an underground utility or a resource or a commonly shared resource then if it is not there you can go as deep as you want similarly if I want to go up a kilometer into the sky we want to make Burj Khalifa, once I own the land, I own the airspace above it unless you are coming in the flight path. For example, the IIT main building cannot be higher than what it is because it is on the landing flight path. So, we

are 8 storeys or 9 storeys, suddenly if we wanted to make a 25 story tower here, we cannot do it because you are on the landing path of the aircraft. So, if there is a common resource being used then I can be restricted.

So, every earth, every person who owns the landfill site wants to used it to a maximum capacity; however, I told you height is restricted from aesthetic considerations 15 meters high means how many storage building 3 and a half meters to a story typically maybe about 4 or 4. So, you do not want your waste dump to rise above the skyline of the city.

So typically, 15 meters high and seven meters deep from excavation concentrations; however, if I have only a 100 meter width and did not ask me sir what is this s high s is the side slope of the above ground portion if I have a 100 meters then I have a problem I may have the same area this may be a square configuration and this may be a very long configuration, but the problem is that this is my airspace and I am using very little of it not even 50 percent not even 33 percent I am using very little of it.

And the other problem is I cannot go as high as I want because 4 is to 1 you only have this is 100 meters wide you only have 50 meters as the horizontal width and the height that you can get if you start from the extreme boundaries is 50 divided by 4 which will be 12 point 5 meters and not 15 meters a this is a critical aspect of landfill capacity.

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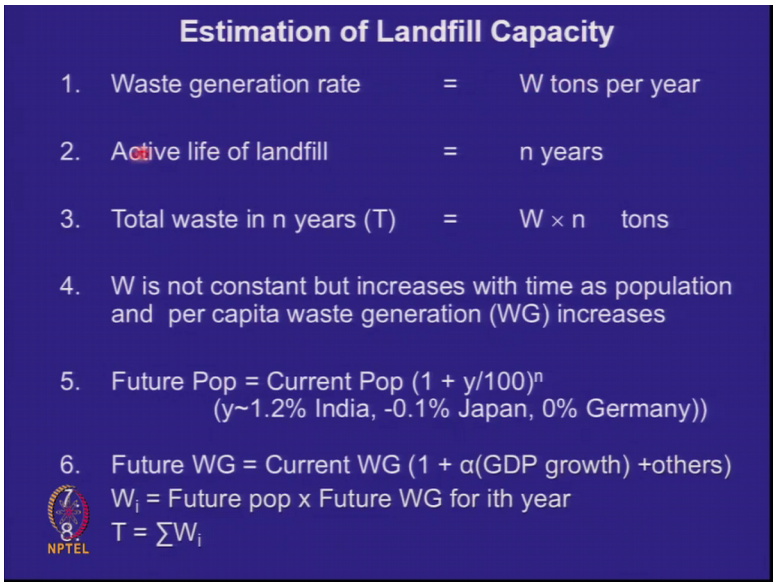

The other thing which I wanted to talk to you last time about was the estimation of landfill capacity and we talked about waste generation w tons per year we talked of n years as being the life of a landfill and we said total waste in n years is w into n. So, I also mentioned that this is not this is a very approximate formula. In fact, this is an underestimation because your population is growing or decreasing and you have to do a correct estimate. And first I have asked you all to come up with some figures about this waste generation per capita per day in various cities. So, I have I have you must have discovered this by now. So, in India what kind of figures did you get?

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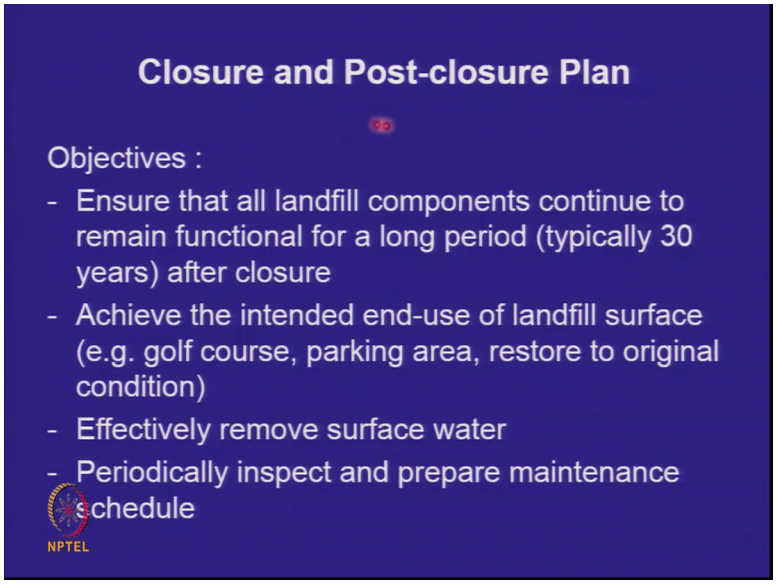

And in another country, what kind of figures did you get. So, anybody would like to give me some figures which you came across?

Student: (Refer Time: 07:33) I do not who (Refer Time: 07:34) about 0.63 kg per (Refer Time: 07:38).

So, Mumbai; we have one figure, now we are talking of kg; 0.63 kg per person per day a anybody has any other Indian city.

Student: Bangalore (Refer Time: 08:01) and Bangalore.

Bangalore; you mean Bengaluru?

Student: Bengaluru.

If you got a figure of 0.39, is it very recent or old.

Student: Before 2005.

Oh, 2005 is very old; your data is for which year?

Student: (Refer Time: 08:25).

I mean.

Student: 2015.

Sure?

Student: Yeah.

So, if this is 2005, I can say that this is like your; if you put money in your fixed deposit, what will happen to it after 5 years, it will double. So, you may like to give me a more updated figure anybody else has a more recent figure of any other city.

Student: Chennai (Refer Time: 09:01).

Which year?

Student: (Refer Time: 09:08).

So, you have the same source you go to Wikipedia great did you go to CP CB or ministry of urban affairs, which website did you attack to know that this is correct anyways I think very revealing, but we are above 0.5 kilogram per person per day in the metro cities. So, anybody has got now figures from overseas mega cities [FL].

Student: Sir, Tokyo.

Tokyo, what was the figure?

Student: 1.38.

1.38; do you have the year and do remember, Tokyo is an island in Japan, I mean, we are in Japan, which is you know water locked, you do not have much space, they want to

keep minimum waste because you do not have much a year to dispose it, they do not have too much land, anybody else?

Student: (Refer Time: 10:08) 2 4 and 2011 (Refer Time: 10:10).

So, that is fine, I mean that is fine. So, we are reconfirming 1.27 in 2011. So, it seems to be recent any other major city in Europe or;

Student: Paris.

Paris.

Student: (Refer Time: 10:27) 1.5 to 12 kg.

1.50 to 2.00; you have the year?

Student: (Refer Time: 10:35) 2012-14 (Refer Time: 10:38).

2012 to 14, anybody in America;

Student: 11 1 4 to 131.56.

Where?

Student: London.

London, any US?

Student: New York.

New York.

Student: 2.75.

Anybody would confirm 2.75.

Student: Sir, 4.5. Sir, (Refer Time: 11:09).

4 point.

Student: 5 sir, it is highly (Refer Time: 11:13) highest (Refer Time: 11:14) city in the world.

4.5; a little bit high.

Student: sir, rebound (Refer Time: 11:19) sir, no sir, not even 2 or 2 to 3 (Refer Time: 11:24) sighted 4.55 come.

So, somebody said 2.76. So, we will say 2.76 to 5.00. So, all that I want to say is this is a huge variation, but clearly the more developed the country the higher the per capita output of waste.

So, I wanted you to get a flavor of this as you go into rural and smaller cities, these values will reduce as we become more prosperous we consume more and therefore, more waste comes up. So, our footprint no longer remains small. So, just to end this the discussion we did this w into n, but we have to remember w is not constant, but increases with time for 2 reasons definitely as population increases and as per capita waste generation increases on account of increase in GDP.

So, future population can be estimated as current population into one plus y over 100 into n where y is the rate of population growth in percentage India it appears to be 1.2 percent, Japan has minus 0.1 percent, Germany has wavered on both sides of 0, it was real low earlier, now it seems to be taking up, but these are estimated rates and you know depends on the time span.

So, one is the population will keep on growing the second is that the waste generation rate will depend on what it is today plus the rate of GDP growth there seems to be a correlation factor alpha. So, we do not want to get into great detail on this, but there seems to be a direct a correlation between waste generations even if your population is constant if your GDP per capita goes up what is the rate of growth of GDP in India.

Student: 6 to 7.

6 to 7 percent, so, this is going to growth, right. So, basically what you need to do is for future years you have to look at the future population you have to look at the future WG for the i-th year and for each year you have to computed and you have to sum it for your n years.

So, this is an underestimate really this is an underestimate and, but this is just a very simple way of looking at things the third thing I wanted to talk about planning which we discussed as you are closing last lecture we talked about the closure.

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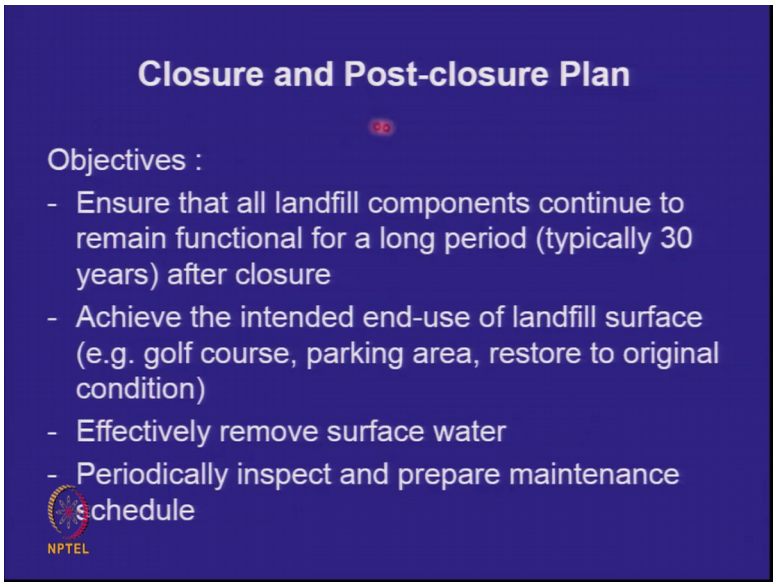

And the post closure plan and our idea is that the landfill component should continue to remain functional till the closure period post closure period is over typically 30 years we must achieve the ended use and suppose the ended use is not golf course or parking area then we have to restore it to its original condition. And we would I would like to address a little more in detail if you are making a golf course or a parking area it will be commercially maintained right you will be getting an income you will be maintaining it you will be getting you will be able to monitor all the signs of settlements of something Leachate coming out from somewhere if at all.

So, you are able to, but if you are not going to be there then how do you restore it to the original condition of course, till that time we have to remove the surface water we have to do the maintenance and we have to do the periodic inspection and monitoring.

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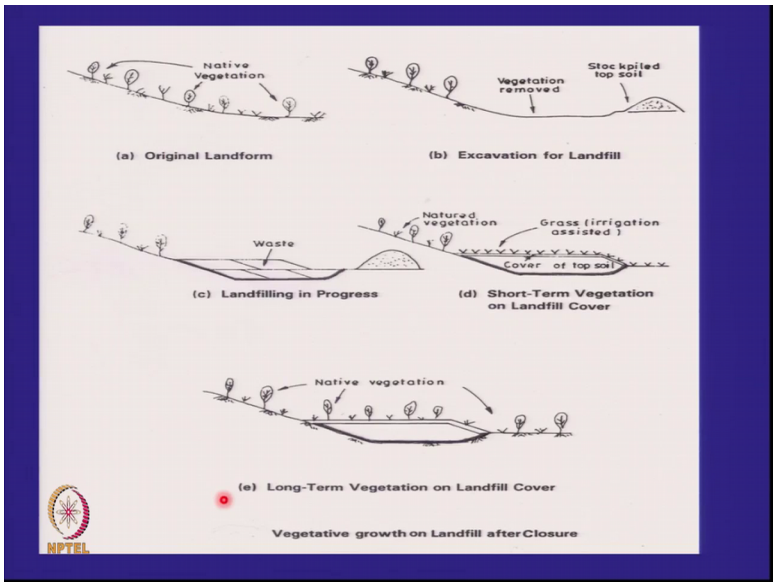

So, conceptually this is what the broad picture of landfills is we found a location which nobody was using for disposing a waste we cleared it up and put a liner and you put our waste in daily cells the nearly phases. And then when it was all over we had a covered landfill and in terms of covers everybody wants a green cover nobody wants a concrete cover nobody wants a black cover in all your water tanks a black remember syntax water tanks, but then people said if black does not look good, let us say white and then you started getting pigmented and different colors of what water tanks.

So, if this is grass and if this is the waste we have to monitor this for 30 years and if you have to walk off 2 things have to be assured that this is me this is stable it is no longer having bad emissions that is number one the second important aspect is grass cannot survive by itself you know you have a garden you have a park grass survives because it is irrigated there is a [FL] the horticultural people are looking after it they are beautiful hedges, but vegetation in the wild survives by itself. So, native vegetation is self supported. That means, it if there is a monsoon and then there is a summer and then there is a winter the vegetation may go from green to brown and it may not be visible for some time, but it will sprout again. That means that vegetation survives without being given additional irrigation water or fertilizer.

So, our aim is that if the waste inside this has become stable before I leave I have to get the natural vegetation back on this because if I do not what will happen the grass will go

after I walk off once the grass goes the binder to the top soil goes and erosion will start and then progressively this will deteriorate if the waste is not stable; that means, the emissions of the gas and the Leachate are not within the acceptable limits of the pollution control board we cannot leave this site and I have told you this then we have to take other measures after the design period as to what to do about it, but this is what we are saying we will do in restoring it to its original condition. So, here we have homogenized or harmonized thick waste with the surrounding environment.

So, this is the larger picture immediate picture of course, is to how not to pollute the environment it can be really walk off a site. So, if you see with most of these cycles of 50 200 years industrial areas if you if you look historically industrial areas start becoming degraded with time we were not taking adequate measures our land was becoming polluted with time.

So, before you could reuse the land you had to rehabilitate the land you to remove the pollution. So, this is exactly what we are talking about. So, any questions on this aspect about the planning aspects which we discussed this 2-3 fine points otherwise you can start with liners great. So, I believe we are all on the same plane and we would like to see that we are looking at the bottom element which prevents the Leachate from going into the ground depending on the type of landfill.

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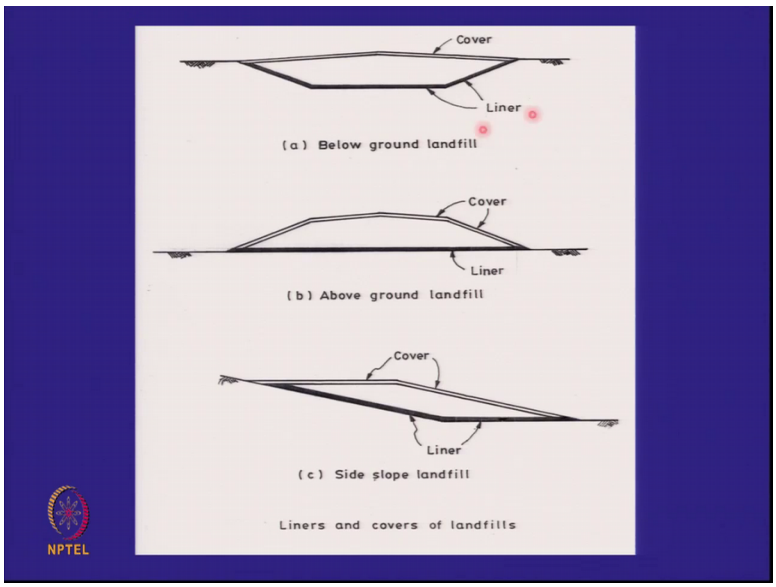

I mean you may have more cover or less cover in comparison to the liner both are impermeable elements or cover in the liner in the dry term concept if it is a below ground landfill you can see the liner is more than the cover if it is an above ground landfill then the cover is more than the liner. And if it is a side slope landfill then the cover and the liner appears to be similar in the quantities involved.

The major difference between the cover and the liner is that both are impervious or have very very very low permeability, but the liner gets buried it is not accessible the cover is always accessible for repair. So, the risk of leakage here is much higher and therefore, this has to be we have to be very careful about the design of the liner.

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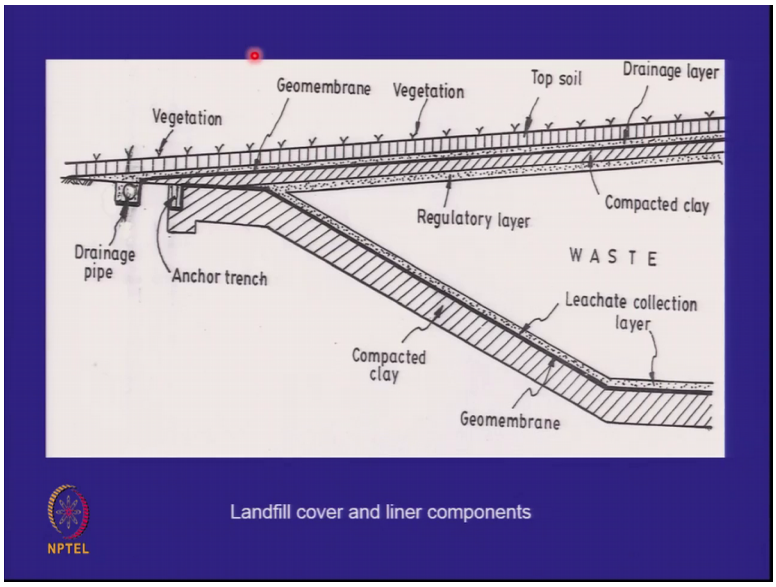

And they have already said this earlier this is just a figure which will keep on coming again and again the cover is a multi-component multilayer device and the liner is a multi-component multilayer device as you go forward this will begin to make more and more sense or all these details.

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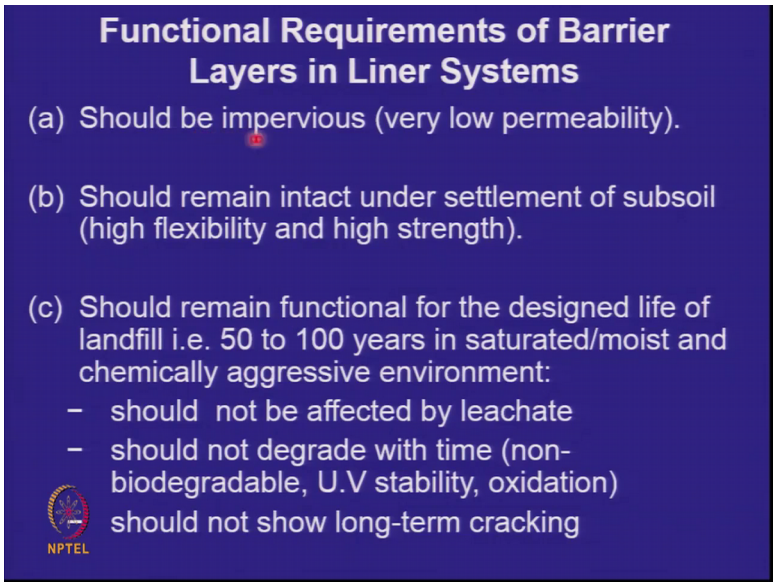

So, what are the functional requirements of the barrier in the liner system we have a hydraulic barrier. So, the first statement is it should be impervious. So, as I said I am not aware of any impervious material I am not aware eventually a liquid will pass through if not by gravity flow then by diffusion by a shear push at the molecular level of the difference in concentration even a plastic sheet which looks impermeable to us eventually a gas comes out of the plastic sheet because you can under concentration and pressure differences have something move not very very very slow.

Our objective is simple whatever comes out of the landfill is like whatever comes out of a factory as long as the emissions are less than the permissible values we are happy. So, when we say it should be impervious what we mean is it should be very very low permeability everything has a permeability, because nothing is a solid matrix and the other put thing is that it should remain intact under settlement of subsoil. Now as you build up your waste you are passing stresses on to the ground the soil will settle a little.

And therefore, whatever you put at the bottom should not be a rigid element which will crack right this is more important in covers than in liners because in the cover the waste itself is settling. So, the settlements are much larger, but that does not take us away from the fact that the subsoil is also settling and god forbid if you are surrounded by loose or soft soil then maybe the settlements can be high.

So, your containment system has to remain intact over and above this it has to remain functional for 5200 years. So, it is not like I can put erudite do you know what is erudite, know what is the what kind of glue are you using nowadays if you have to stick 2 pieces of wood together or 2 ply plastic something breaks what do you use to put them together to join them.

Student: (Refer Time: 22:40).

Louder, I cannot hear you.

Student: Fevy quick.

Fevy quick, so, everything has to be quick. So, my erudite of a Erul quick that is what I meant. So, the point is you can join something, but if that material with which you join it with time shows some kind of shrinkage or cracking then it is not the material that we want. So, we must be sure that the material with which you are working will remain for 5200 years like we are sure about bricks like we are sure about concrete and we are also sure about the reinforcement bars, but sometimes when there is a lot seepage of water then corrosion does occur and it does cause spoiling, but we do know that cement bricks concrete these are materials which will last for 50 to 100 years.

So, you must have that and these should not be affected by Leachate, no, the Leachate can be of various types you can have Leachate from a municipal solid waste landfill you can have a Leachate from a hazardous waste landfills and you can have a Leachate from a construction and demolition. So, the intensity of the concentration will change and also the constituents. So, it should be able to withstand the Leachate you see many times concrete floors if you go to chemical factories if acid is falling on it a ph, is a high or low it starts to affect the flooring.

So, we need to have a material which is not affected and it should not degrade with time, there should be no degradation of the material like ultraviolet stability sunlight or oxidation what example can I take if you have a plastic chair and if you leave it in the sunlight for a long time the plastic becomes more and more rigid and more and more rigid. And one day it cracks maybe this happens to your hostel chairs as well if you have a hosepipe by which you use for gardening your water and you leave it in the sun or leave it in the open not even in the sun with time it becomes more and more stiffer and

stiffer and then you eventually it cracks. So, these are not materials which are remaining stable with time and oxidation is a big culprit when we are when we are talking of something for a year that is fine.

But when we saw talking for something for 100 years then we have worried about oxidation and you and I are getting oxidized is that right to live longer what do you have to have antioxidants. So, first we are breathing oxygen and then we are saying we are getting oxidized. So, we everything has get affected eventually in a very slow way by oxidation. So, these have to be stable against oxidation for this long period and should not show long long term cracking; that means, works fine today does not work fine after ten years that is on all there many more things the liner has to do it should withstand the load due to moving men and machines. You are going to put spread the liner in a football field then you are going to spread the waste well maybe the dozer will not directly move on the liner, but there will be a layer of waste, but people are moving on it the people who are spreading the liner are moving on it.

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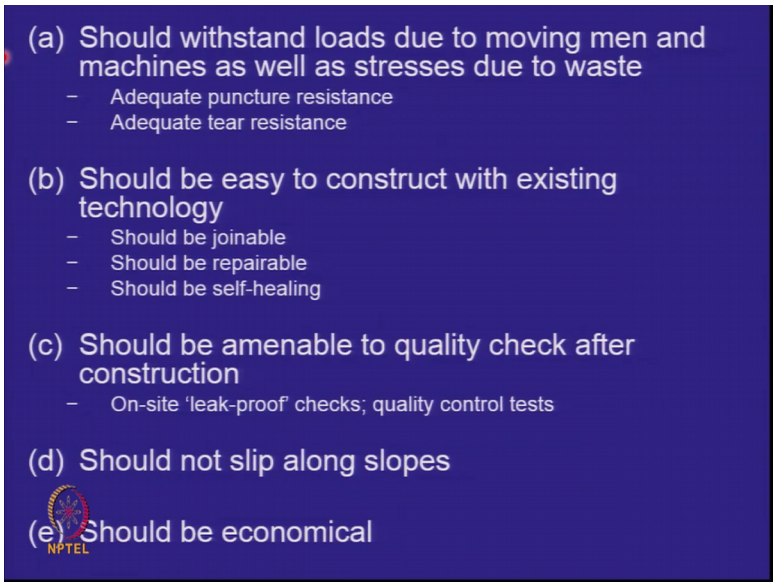

So, it should not be damaged by moving men and machines and it should not be damaged by the stresses coming on account of 15, 20, 30, 40 meter high wastes, this should not give should be easy to construct now there are 2 types of materials those which are prefabricated. And those which are constructed on site and this typically the problem in your institute of construction was a spin prefabricated construction

prefabricated construction brilliant everything in the factory perfect temperature pressure pH humidity everything comes out wonderful on the side depends on the mood of the operator of the labor. And if he is not in a good mood god help the quality of joints is going to be that much different from what he does all the time.

So, we prefer prefabricated stuff because its better quality, but when you get prefabricated stuff it can own it of a limited size whether it is cloth whether it is polymer whether it is a bitumen bituminous sheet all these may come in the form of a roll, but still it is limited size whatever is being done institute is not limited in size except if you want to stop working. For example, when you put the roof of your house how many of you been involved in a construction of a house either in your B tech project or your father's house a grandfathers house how many of you actually seen a roof being cast one I cannot believe 2 many of you. So, what is the critical thing about the roof, when you cast a roof, when you have been concreting of a roof? And I am talking of RCC roof what is the most important thing.

Student: Is to be completed in one go.

It has to be completed in one go you cannot say I will put half the roof today I go home and sleep have a hearty meal and I will come and do the other half of the roof tomorrow I can join the 2 there is not an issue that the material will not join, but you will get a joint. So, when you do in situ construction you can make as big a thing as you want provided you are working 24 7.

So, in situ of construction requires that there be no coal joints no construction joints no abrupt stoppage see what will happen suppose I do a roof in one go I started in the morning it did not complete by the evening I put on the floodlights I got second shift of labor the concrete kept on coming fresh, fresh, fresh and move forward the back part of the concrete was setting the front was fresh, fresh, fresh, fresh now if another guy does not do that he says I will take a break I will come after eight hours this concrete has set the new concrete is fresh you can chisel around and make the contact intimate, but always between the fresh concrete and the old concrete there will be a joint that will become a preferential path of seepage.

So, should be easy to construct with existing technology if you are getting prefabricated then they should be joinable if you get something which gets damaged then it should be

repairable I mean you are working with a plastic sheet your screwdriver falls you get a hole in the plastic sheet we got to repair it and some people say it should be self healing I mean you forget you forget to heal it, it should heal by itself like your wound you have a self healing wound you have a small cut you forget about it we all right. So, do we have self healing materials maybe they will be biotic maybe they may not be biotic it should be amenable to quality check after construction you can always say- sir, I have made impermeable barrier for you I do not I do not believe you I want you to prove to me that its leak proof.

So, if you have an overhead water tank its above the ground if it leaks you will get to know you will fill it up with water, but if you have a liner below the ground and then you cannot go into the liner to check the leakage. So, it should have on site leak proof checks quality control tests should not slip along slopes and liners you have slopes in cover you have slopes which should not be something which slips and in the end it should be economical.

So, this may not be that important, but between alternatives which fee which satisfy all the above you should take the most economical alternative. So, now, I have given you the boundary conditions now you tell me the materials that we are that we are used to using for being hydraulic barriers as I said we are making a hydraulic barrier first we are not going to look at cost we are not going to look at cost just tell me the materials which you think function well as hydraulic barriers.

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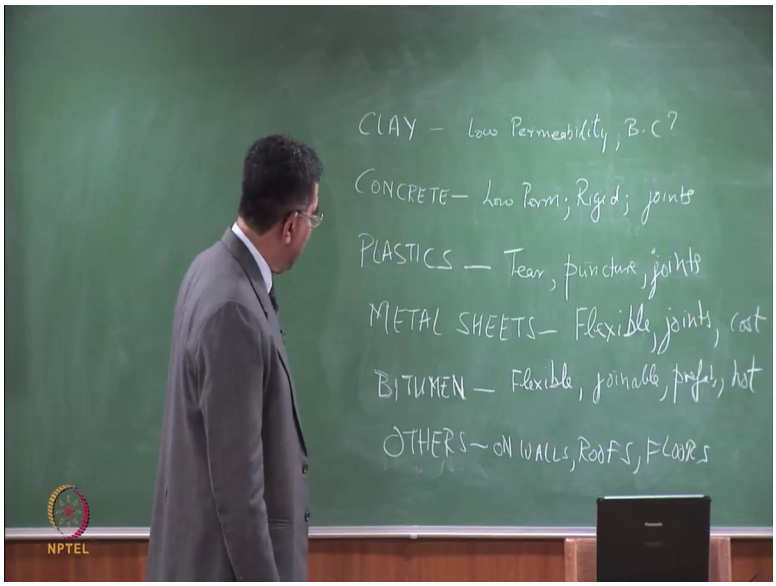

Student: Clay.

Clay, clay is not impervious, it is low permeability, anything else you have, all the money I am going to give you, a million dollars money is not a constraint, let us look at the best materials that we can use to meet all our requirements.

Student: Concrete.

Concrete, what else I mean everything with your water tanks are made off is a good indicator that if it can water tank and hold water quite clearly it is a hydraulic barrier. So, what else?

Student: Plastic, plastic.

Plastics;

Student: Metal sheets.

Metal sheets, I mean many of the basements if you will go they will put aluminum sheets next to the retaining wall so, that the water will come in. So, metal sheets, so, we got steel tanks we got concrete tanks we got plastic tanks we do not have a clay tank, but kind of clays were anything else what kind of sealants water barrier do you use in dams what kind of water barriers do you for do you used for waterproofing. And we are just going to look at all the civil engineering materials with which we deals we see which one

is the one which can help us now you know DPC; damp proof course, what do you put on a damp proof course, for preventing the water derives of the walls.

Student: (Refer Time: 33:26).

No we do not put aluminum sheets in a damp proof course.

Student: PCC;

PCC also is not impervious you know if you may again I asked you were you involved in construction of a house a room if you are not go and watch the construction which is taking place next to the LHC on the as you approach the LSC on the left side something is being constructed.

So, I do not know what they do for DPC nowadays, but in my time they used to put something which was black.

Student: Bitumen (Refer Time: 34:04).

Bitumen coal tar whatever you want to call it that was waterproofing material. So, bitumen, so, you get these so many waterproofing magical things for walls investments some you can put buy a brush some you can spray and these magical things. So, let us put magical things at the bottom others and in this can be epoxies these can be raisins these can be sprays this can be brush ones these can be emulsions all kinds of stuff used on walls used on walls roofs and floors. So, these are the various alternatives. Let us now see what can work and what cannot work clay what is the problem it is not impervious has some permeability and water will eventually come out it can anything else it is has some low permeability that is one problem anything else can you take the stresses can it take the stresses of a 30 meter high waist now I will you have a bearing capacity failure.

I do not know what about concrete, concrete also has low permeability probably lower than clay if it is well compacted well vibrated, but what is the other problem with concrete is it flexible or is it rigid.

Student: Rigid.

It is not likely to take settlements is clay likely to take settlements or will it concrete will clack crack I mean. So, PCC will crack, RCC will also crack.

Student: E can design un-cracked.

We can design.

Student: Un-cracked section.

Un-crack section of what sites I am I am trying to put a concrete floor 500 meters were 500 meters just for you to get the idea this is 5 football fields in this direction 5 football fields in the other direction else. So, that just about puts us in its perspective maybe it is a size of all those lawn tennis courts that you have between the hostels on that side.

So PCC will crack, I cannot make an RCC slab which is that white I have to give joints I have to give construction joints. So, the moment you give construction joints, it is no longer a problem about the impermeability of the slab it becomes a problem of the in permeability of the joint or you can always put all kinds of water stops and you know sealants, but joints are more difficult to see you than the parent material.

So, there are issues of low permeability rigidity and joints plastics, plastics are almost impermeable almost, but they also have low permeability very very low permeability much lower than clay and concrete, but do plastics have some other problems.

Student: Puncture.

So, these are puncture tear. So, and they also have problems of joints because plastics will come to you in rolls. So, what is the widest width of roll that you can get to a site?

Student: 3 meters.

3 meters, so, there is a suggestion that it is 3 meters well one thing is very clear I would like as wide a role as possible because then the number of joints goes down right. So, how much is the widest roll the 2 limitations how wide can you manufacture and how wide can you?

Transport, took as may transport Korea, I have this great simile that you know the space shuttle I have done this with you before if I have let me know. So, the size of the space shuttle the width and the diameter is governed by the size of the backside of a horse and what is this inter linkage you have a you have a space shuttle and it has to be put together. So, the jets are made somewhere else the chambers are made somewhere else

the payload and the top is made somewhere else and all these have to come together at one place assemble and either you assemble everything at the site or they have to come from somewhere so; that means, everything is governed by transportation, how do you transport things, I do not transport anything by a horse.

Student: (Refer Time: 40:28).

And not nowadays when Sherlock Homes used to be there if you are watching the serial then you used to go in a lovely horse carriage way right, but today it will either come in a truck or it will come by ship or it will come by a helicopter or it will come by a train forwards by land by water by air.

So, the helicopters can only drift this much and bring it along. So, I think the propulsion jets of the space shuttle are sent by rail. So, you can have a narrow gauge in India or a wide gauge or maybe even a wider, but once you are sending something by rail its size is fixed by the size of the rail track you can overflow a little bit, but you cannot send a hugely why you cannot take this room on a on a railway back right. So, whether you send it by roll road then you have to undergo go beneath flyovers the size is limited you send it by rail you have to go through tunnels the size is limited you try and pick it up by helicopter well I do not know how many helicopters will pick up this building you have the payload issue you can send it by ship show pick it up by crane, but does the ship reach where you want to launch it from it may not.

So, if you are going by train always remember that the width of the track what governs the width of the train track a road is of variable width you know single lane, 2 lane, 4 lane, 6 lane, express ways of how many lanes; 4 this way, 4 that way, 5 this way, 5 that way, you have got 8 to 10. So, what is the width of a road it can be as small as 3 meters when you are going to a village and it can be as wide as;

Student: 3.75.

3.75; you can be as small as 3.75 meters and how wide can I express maybe.

Student: (Refer Time: 42:33).

50, do not bother, I mean the go to gone out tall probably 50 meters wide, how wide is the rail track.

Student: (Refer Time: 42:46).

So, where did this come from why did that make this real track one or one point something meters wide I mean who fixes a wide in then make it 3 meters wide. So, you can go back historically what I understand is that when the rail came before that the mode of transport was the horse with the carriageway 2 horses put together used to pull a carriageway, right.

So, the width of the wheels of the carriage cart or carriers decided by the width of the backside of 2 horses standing side to side with sufficient clearance. So, when they started to put the rail tracks they had to put it in areas where there was no road, but only horses used to go and horses not the ones which went without a rolling carriage way because then they could go in any which way because they have a hopping motion. So, the rolling carriage wave went at greed slight incline.

So, all these are already laid out. So, the tracks were put in the impressions of the wheels of the carriage. So, the size of tomb backsides of 2 horses governed the width of the carriage way track and on it went the rail and that is a real track tony of course, there must be other considerations why I did not become wider with time.

But eventually the propulsion jet of the space shuttle it comes on a real track and therefore, the maximum diameter that it can have is governed by the back side of a horse because if the back side of a horse had been larger the real track would have been wider and you would have been able to put wide more wider propulsion unit on the track.

So, the same thing applies there I want to send in a huge role what is the length and what is the width of the roll. So, if I am sending it by truck then the width of the roll is I can put the roll lying down. So, there are certain limitations. So, plastics we said tear puncture joints, but one can always make a plastic which is going to be puncture and tear proof and a very simple example is the my shoe has a top your shoe as a top right and you walk in it you play in it something falls on it does it puncture.

I am not talking of the sports shoes which may have cloth, but if you have a leather shoe or a plastic shoe then you will notice that the top of a shoe will last you for 4 or 5 years or maybe 3 4 years you agree with me on that if I draws a drop a screwdriver on this maybe my toe will break, but my leather will not have a hole in it. So, if I make the

plastic sufficiently thick I can definitely ensure that it may not get damaged during installation, because if these were to get damaged every time I hit something then I would have to buy a new pair every few days and we do hit it across ever so often.

So, please remember we can take care of this issue about being tear and puncture metal sheets no problem they are also flexible to some extent well again there is a issue of joints and currently metal is more expensive than plastics on a performance basis. So, their issue of cost bitumen wonderful material clays prefabricated or on site it is comes from a borrow area, but it is spread on site and compacted on site concrete is prefabricated or institute.

Student: Institute.

Institute construction plastics prefabricated they come from a factory metal sheets prefabricated they come from a factory bitumen, bitumen comes to you in drums main element of bitumen is it has to be heated then once it is heated its liquidly you can spread it and then it sets.

So, working with bitumen is difficult given a chance would you be working in an asphalt tech plant laying roads or would you be working on a concrete roof given a chance suppose you have to work ten hours a day just installing or constructing with bitumen and constructing with concrete which would be prefer working at the ambient temperature is easier than working at an elevated temperature. So, issues of quality control when you work with hot material the issues of quality control.

So, bitumen is good it is flexible and because it is in situ the issue of joints does not come you can keep on spreading it as long as you are you can also get it in the form of sheets. So, bitumen is both you can get bituminous sheets for example, you have the bituminous sheets for putting on your roof top they have a plastic or you know a polymeric base on which the bitumen is already pre spread and you can roll it out and heat it and join it and bitumen is easy to join you can heat and join heat and join. So, bitumen is flexible joinable it is also prefab, but it is hot and not hot as in hot and happening hot as in hot and burning otherwise you get a lot of these words which are used others. So, other than these materials we have others.

So, what about all these waterproof paints and waterproof sprays and waterproof liquids what is what about them which are used in walls. So, these others work well on a strong plain substrate I mean if you want to paint something you need a wall would you like to paint something on soil what will happen I asked you to paint this is soil please paint some impermeable liquid on it; what will happen? You will take a brush and you will paint it, what will happen?

Student: Some will get painted some will not some will (Refer Time: 50:13).

Why will it not get painted?

Student: (Refer Time: 50:16) not like connected to each other.

What you are trying to say I think is that when you will put the paintbrush on the soil instead of the paint going to the soil the soil makes it stick to the paintbrush that is what you are trying to articulate the substrate is not strong and uniform. So, you cannot paint anything on soil the soil might want to paint itself onto the material that you are trying. So, you may not be able to transfer it to the soil.

So, all these things which are these magical reasons polyurethanes and waterproofing compounds they work well on walls and floors and roofs because the base is very strong and you can spread them very thin and very uniformly on soil there 2 problems you do not have a plain thin flat finish you just do not have it I have already told you; you want to have nuts moving you want to use a dozer to make the bulldozer to make your ground flat well it is only that flat; it is not like flat as in the bathroom floor where you know you can give an inclination of one in thousand our flat will be undulating flat.

So, that is first issue that you do not have a perfectly horizontal and the second issue is that the soil particles specially if you try and think can I put paint on sand no can I put a spray on sand yes, but the moment you put your foot on it you will just displace itself. So, these all do not work.

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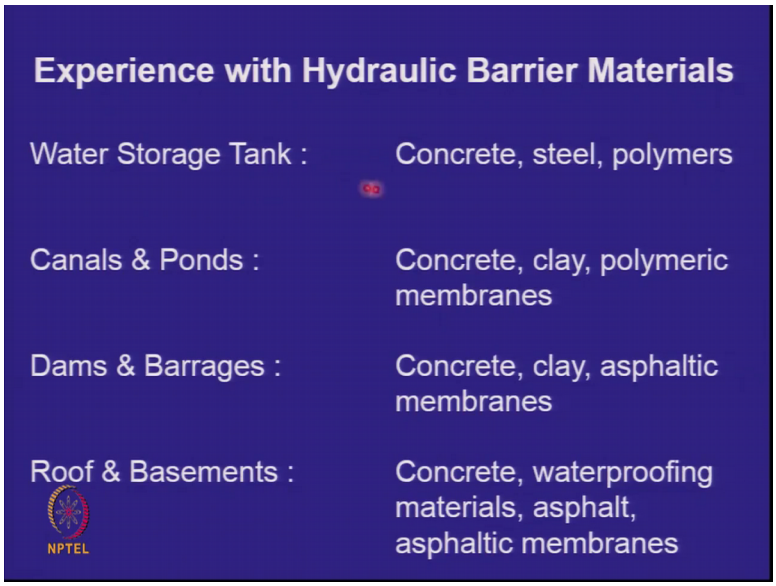

So, quickly, we worked with water storage tanks you can have concrete steel polymers in canals I use concrete I also have brick lining I have clay I have polymeric membranes the word plastic I am using polymeric here dams and barrages we have concrete cores make concrete for stopping.

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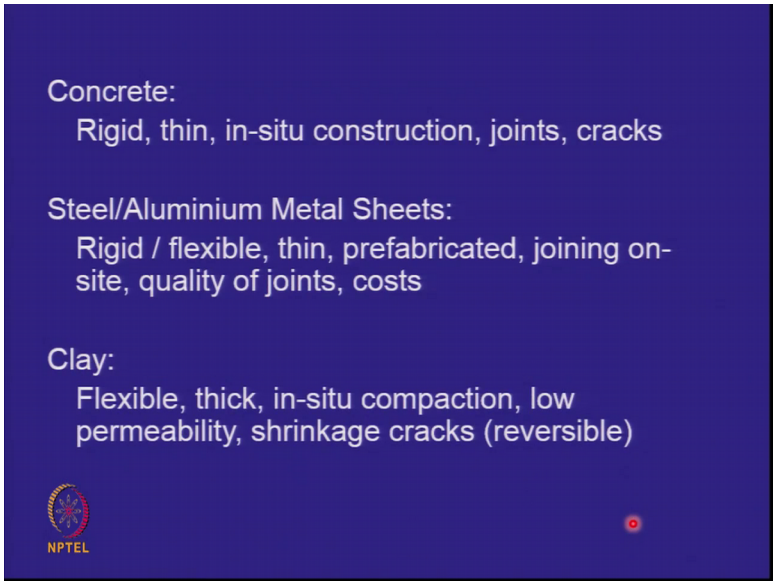

The water clay cores asphaltic membranes roofs and basements concrete waterproofing materials asphaltic membranes asphalt, so, as I said concrete rigid thin in situ construction joints cracks steel aluminum sheets rigid or flexible thin prefabricated

joining on site quality of joint and costs clay flexible clay has to be thick you cannot put a few millimeters of clay and say I have got an impermeable barrier. So, it has to be thick means it may has to be in terms of meters in situ compaction it has low permeability, but it gets shrinkage cracks.

So, when you see this when a drought comes you know all these periodicals and magazines will show farmers sitting on a dry field and you see this hexagonal patterns in the soil and those are shrinkage cracks. And the dry lake bed on which he is sitting is the clay at the bottom of a water pond when it dries it gives you shrinkage cracks, but do remember these cracks are reversible they are self healing if you take a clay which has shrunk and you give it water what will happen if it can shrink it can swell.

So, these shrinkage cracks do close themselves and therefore, they are reversible this is an important thing because one of the great negative aspects highlighted in clays are shrinkage cracks and you feel- oh, this crack is 5 millimeter right. All the water will go down, but the fact is every time a lake dries up or a pond dries up and rains come again all the water does not go down because the cracks heal.

So, they have a self healing capacity.

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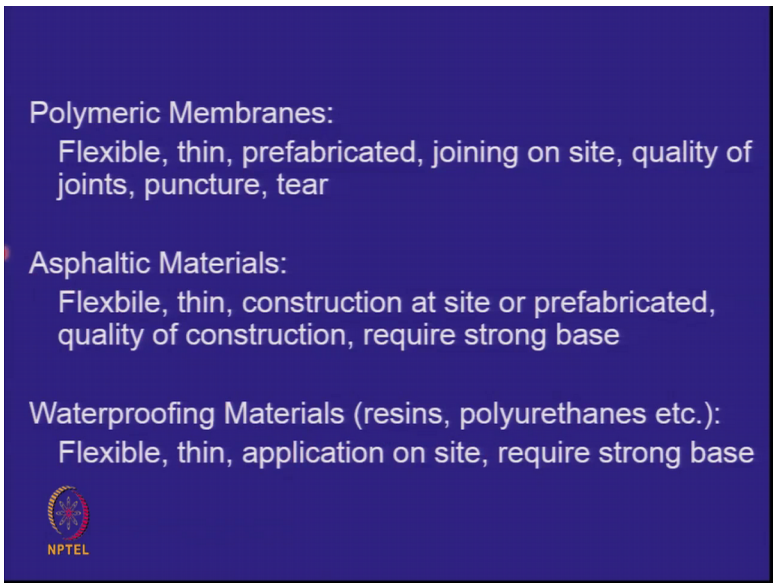

Polymeric membranes flexible thin prefabricated they have to be joined on the site the issues about the quality of the joining the puncture and the tears asphaltic materials

flexible thin construction at site or prefabricated quality of construction they also require strong base and you have to work in a hot environment which I have unfortunately not written here. So, maybe I would like to add that. So, hot working temperature waterproofing materials flexible thin application can be done on site, but they require a strong base.

So, quite clearly I am not are you able to get one material which you can use from all that we have discussed what we have written here do you have one material which you would like to use you would like to use plastic and then you will assure me that there will be no tears and no punctures and when you join and when you join these things together the joint will be 100 percent leak proof.

Well, unfortunately I have not seen even one plastic installation where there has been a perfect waterproofing it is like you know you have this the vegetable vendor he will have a thin plastic sheet the blue one, but if there is one pin pricken it the water will keep on coming out from that side.

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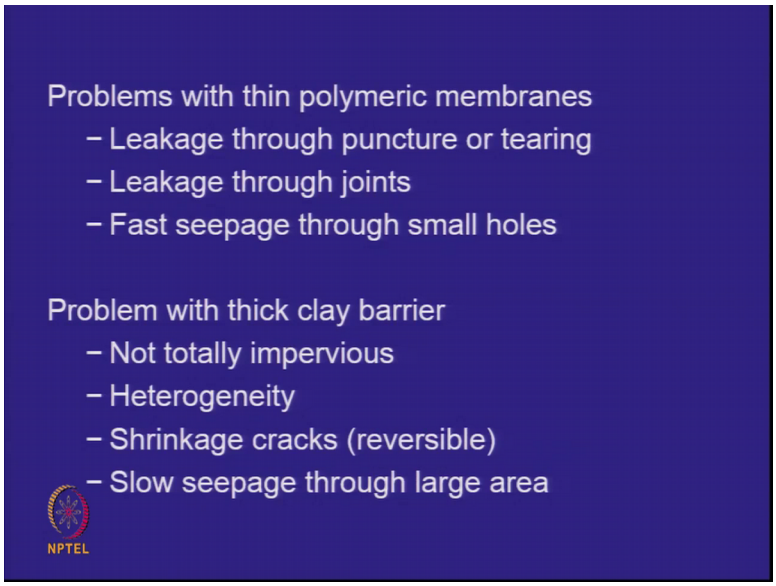

So, what it appears is that what experience shows is that with thin polymeric membranes leakage through punctures or tearing even if we take the maximum precaution there will be some holes. So, this gives you fast seepage you make a puncture in plastic sheet water will come out very fast problem with thick clay barriers there they are not totally impervious there may be some heterogeneity of the clay there may be some shrinkage

cracks. Therefore; you will get slow seepage through large areas. So, the answer to our problem is a composite barrier we do not use one material at the base of a landfill no single standalone material.

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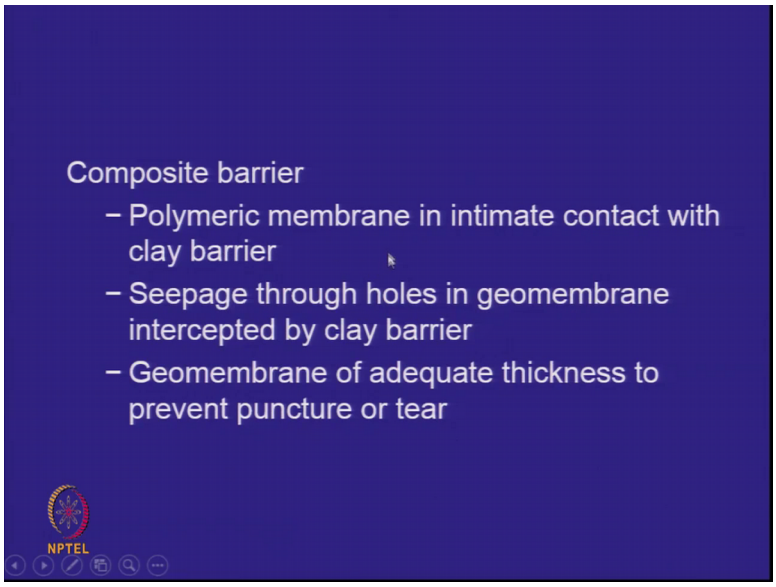

We are talking of a polymeric membrane in intimate contact with a clay barrier that is the liner that we use there may be some holes in the geomembrane, but the moment there are holes in the geomembrane they will be stopped by the clay and try and use a geomembrane of significant thickness to prevent puncture or tear, but even despite that you get punctures or tears in the field.

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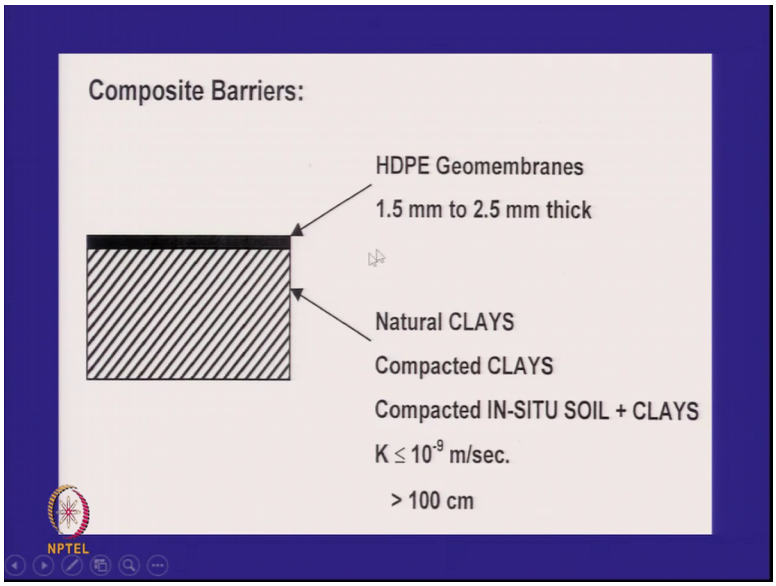

So, let me first come here this is what the composite barrier is typically we use a high density polyethylene geo membrane which is 1.5 to 2.5 mm thick this is pretty thick and it rests on a clay which must be at least one meter thick it must be compacted and the permeability is specified it should be less than ten to the power of minus nine meters per second.

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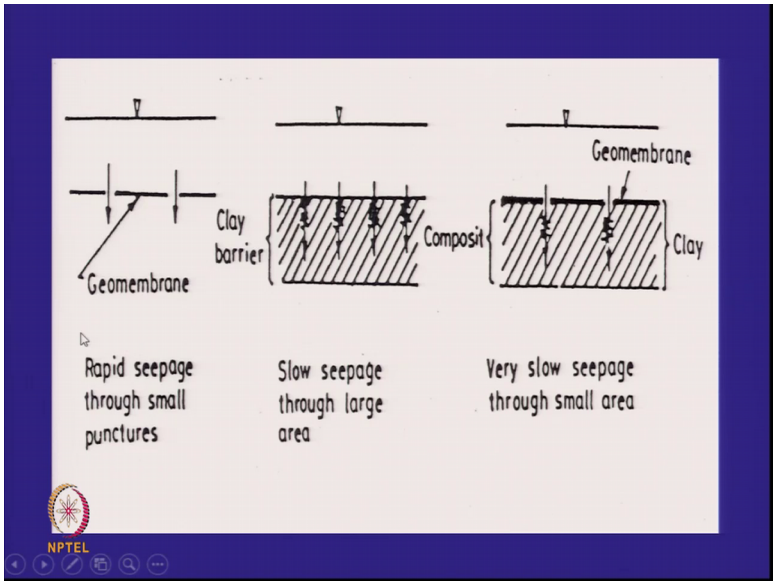

Or 10 to the power of minus seven centimeters per second this is called a composite single composite barrier or a single composite liner system and you just understand the

fundamental principle, it is very important for you to understand you have a geomembrane. And I have to put 2 pin pricks in it and all the water will finish which is standing on top is no way it can hold water, you put a clay barrier water will not finish it will always remain on top, but it will come out drop by drop eventually.

Eventually it will come out I put the geomembrane in close contact with the clay please understand intimate contact then what happens the large area of the clay no water is coming this through the pinhole water comes and it is stopped by the clay so rapid seepage through small holes slow seepage over the entire area very slow seepage through small area. So, all this which does not have any puncture the clay will not allow any seepage and where there is a puncture the clay will inhibit the seepage.

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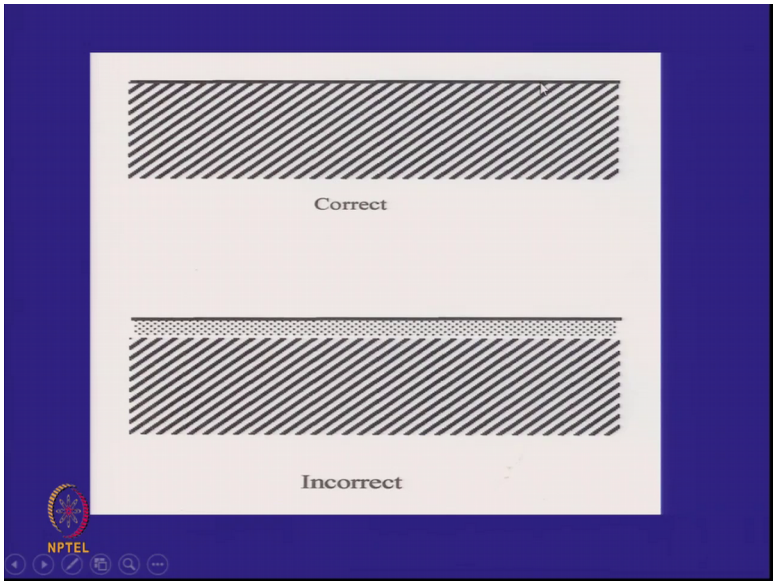

So, this is the concept of the system and remember many people install this wrong this is correct you have a clay at the bottom and geomembrane at the top if you do not have intimate contact please understand what is happening suppose you have sand in between or you have an air gap what happens you have a hole here the whole thing becomes filled with water if the whole thing becomes filled with water you again have water over a large area and the entire clay will seep.

So, critical to this is that if you have a hole here then the water should not be able to travel laterally under the surface of the geomembrane or of the polymer the clay should be there images. So, need intimate contact and that is called a good installation condition.

So, I just again bring this back to you the most critical thing not written here is the intimate contact if there is a little bit of air gap or. So, permeable soil in between you will have a problem.

I would like to sort of cry and wind up now a single liner system means it is not composite it has one of the elements right it may have clay it may have geomembrane, but it is not composite a single composite liner.

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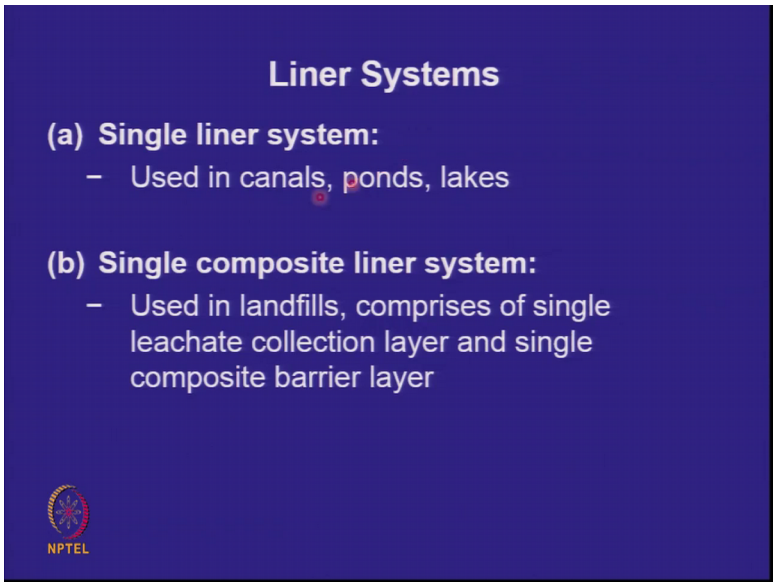

So, please understand single liner systems are different from single composite liners single composite liner is what we saw clay in intimate contact with geomembrane you can have a double liner system 2 walls or 2 polymeric, you have double walled overhead tanks an inner wall and an outer wall, but they are not a they are not they are not double composite liners double composite liner means repeating the element.

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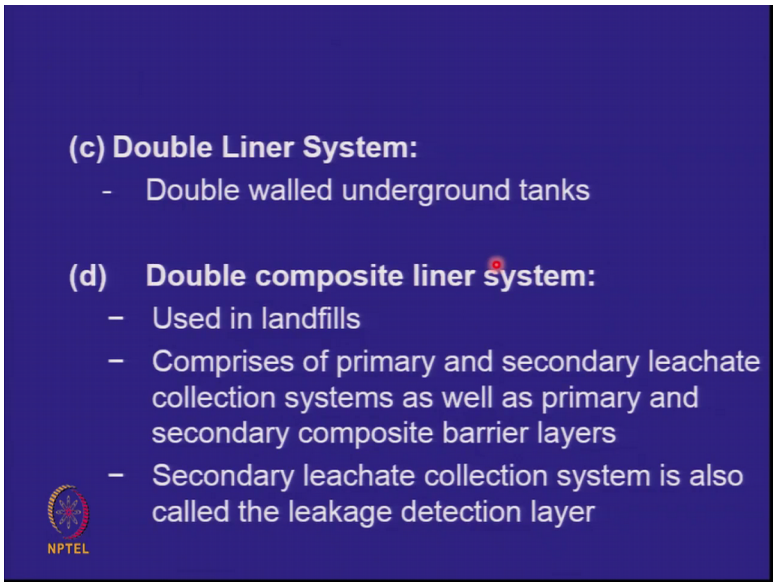

And quickly I bring your attention to the bottom 3 diagrams this is a single liner system only clay maybe it will be used in a CND landfill.

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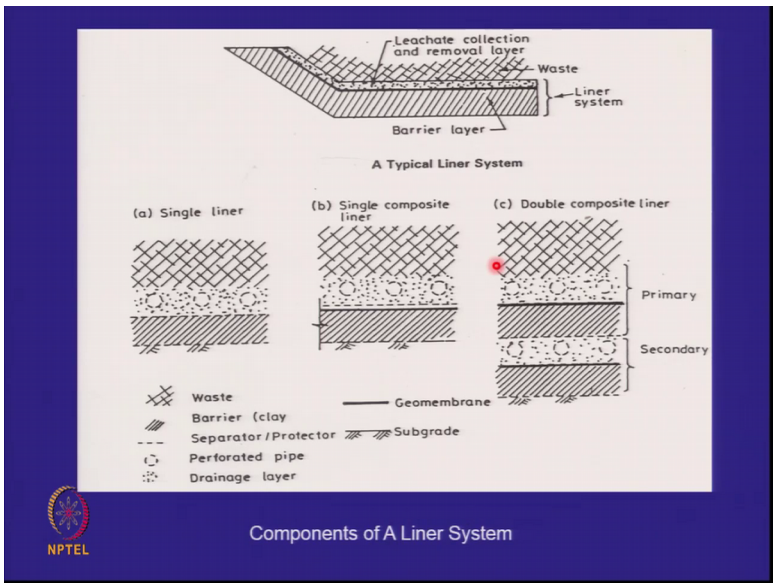

This is the waste there is a little bit of sand and pipes which we will explain next time what they are, but the waste rests on clay, it is a single liner system not used.

So, municipal solid waste landfills not used for hazardous waste landfills the minimum requirement for municipal solid waste landfills is a single composite liner there must be a geomembrane in close contact with the clay and the minimum requirement of hazardous

waste landfills is a double composite liner please distinguish between double liner and double composite liner what is a double liner if I put one clay and one clay with a drainage layer in between its a double liner, but a double composite liner or if I put one plastic sheet a gap. And another plastic sheet that is a double liner, but that is not a double composite liner a double composite liner means one composite liner here and another composite liner.

So, this is typically used for hazardous waste landfills and this is typically used for municipal solid waste landfills and such a system can be used at c and d waste landfills. So, let me revisit what I was saying we do not use single liner systems for landfills except for c and d are inert wastes; however, single liner systems are used in canals you put plastic sheets in canals you use it in ponds you use it in lakes do this for drinking water reservoirs or water reservoirs single composite liner systems used in landfills double liner system not used in landfills, but may be used in double walled underground or overhead tanks double composite liner system used in landfills.

So, these go for hazardous waste landfills and the others go. So, I leave you with these diagrams we will discuss what this is, but this is the Leachate collection layer we always said there will be a straw on top of the liner. So, we have a sand layer here or sand and a gravel layer here. So, if there is any Leachate it will be taken away by these pipes. So, you have the waste the Leachate collection system and the liner we are only discussing this today Leachate collection systems we will discuss in the next class.

So, if there is any clarification or doubt in your mind that you would like to discuss you are welcome. So, we have introduced the concept of a composite liner and we introduced the concept that no single material is a good standalone containment system for 5200 years. So, with this we stop.

Thank you.