Geoenvironmental Engineering (Environmental Geotechnology):
Landfills, Slurry Ponds & Contaminated Sites
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Lecture – 25
Cost of Geotechnical Components of Landfills

Welcome to this class today we are going to discuss how can we get an estimate of the cost of a landfill. So, as I was discussing with some of you if you have to make a 1000 square feet house for yourself and assume that the land is free, 1000 square feet is a single bedroom house two bedroom house or a three bedroom house.

Student: (Refer Time: 00:56) two bedroom house.

I think even three bedrooms in 1100 square feet is made due the Delhi development authority gives you a three bedroom flat 1100 square feet very nice you do not think so.

Student: (Refer Time: 01:16).

Well carpet area, super area, net area let us assume that if I want to make a house of 1200 square feet do you know how much it will cost today rough idea, means you are going to buy a house how much money should you have in your pocket to buy a 1200 square feet flat or a house excluding the cost of land. So, as our friend was telling us that in the CPWD manual the unit rate would be approximately 1200 to.

Student: (Refer Time: 01:53).

To 1500 rupees per square feet and therefore, if I am having a 1000 square feet flat at 1500 rupees per square feet it will become 1500000 or it will become 15 lakhs of rupees. I will need 15 lakh rupees in my pocket to go buy up a house for myself or a flat for myself. Your question is do we know how much landfill cost, just like a no per square feet it cost so much to build a house I should know per square feet it cost so much to build a landfill. Now the issue is that in landfill the heights can vary a lot you can have a landfill which is seven meters high you can have a landfill which is 15 meters high you can have a landfill which is 30 meters high.

So, quite clearly unlike in a residential area where we are talking of one level of living and therefore, the height of that floor space is three and half meters here you will have different costs. So, what I am going to do today with you is try an estimate how much do landfills cost of their about 15 meters high and I am not going to focus on the total cost of landfills I am going to focus on the cost of liners and covers and the other geotechnical components of landfills. So, intuitively now let us try and focus on this.

Suppose I have a landfill which is 100 meters by 100 meters in area or 1000 meters by 1000 meters in area 100 meters by 100 meters football field 1000 meters by 1000 meters 100 football fields 10 football fields like this 10 football fields like this. So, the question that we are asking is how much would this cost. Do we have just like we just now we said 1500 rupees per square feet do we have a thumb rule how many 100s rupees per square yard or per square meter that is what we would look at. What do you think is the bulk of the cost of a landfill in a house what is contributing to the cost of the house? Cost of the construction materials. So, it is the cost of the RCC that is the concrete and the reinforcement and the brakes basically bulk of the cost is the cost of the materials plus the additional cost of construction which is the cost of labour and the skilled manpower what do you think constitutes the cost of a landfill. The cost of the linear the cost of the cover and there may be a replacement cost of the waste inside it. So, that would cost with the cost of a landfill additional cost will be the road that I have to make the small buildings that have to make right the apartment works the drainage channels.

So, we have got look at a landfill where we are not going to take into account the other cost you know somebody has to put a composting plant that may be a separate huge cost somebody wants to waste to energy plant that may be a separate. If the entire lands that we have is going to be made of a landfill with waste dumped on it and the pertinent infrastructure is nominal what is the cost that is what we look at and intuitively one feels that may be the cost of the liner and the cover is the dominant factor, right.

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As we said the focus today is on the cost of geotechnical components of landfills which are the liners and covers I am not going to focus on the cost of pipes in of the pumps in of the sumps because those will be also additional costs. But just like in a house the cost is basically of the concrete and the reinforcements in the brakes it is not about the plumbing in that 1500 rupees per square feet that we are talking of we are not talking of the most expensive fittings of taps which cause the roof like a five star hotel we are also not talking of the cost of tiles in glossy finishes is which cost a lot we are talking of the basic cost. So, that is what you are going to look at here.

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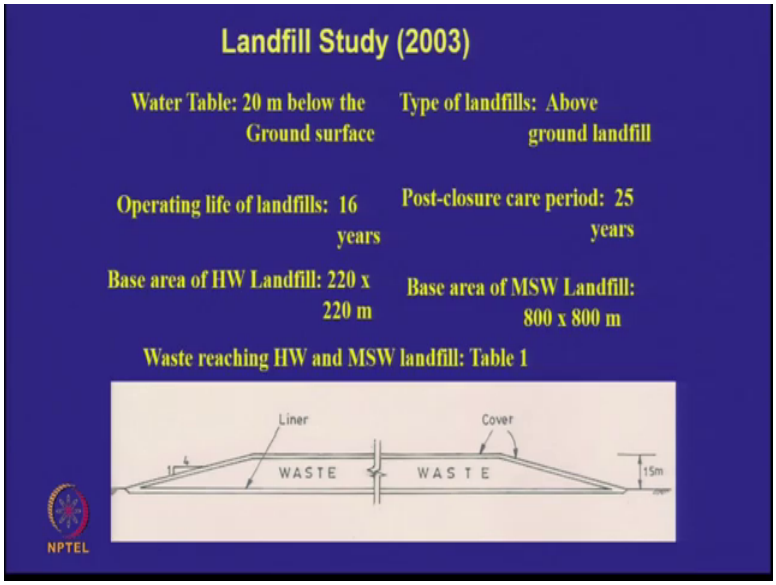

So, first I would like to look at a landfill study and this landfill study for the year 2003 it is for an above ground landfill water table was 20 meters below the ground surface operating life for 16 years, post closure care period 25 year 2 types of waste has it is waste then the size of the landfill is 200 meters by 2 meters 220 meters by 220 meters square and municipal solid waste 800 meters by 800 meters.

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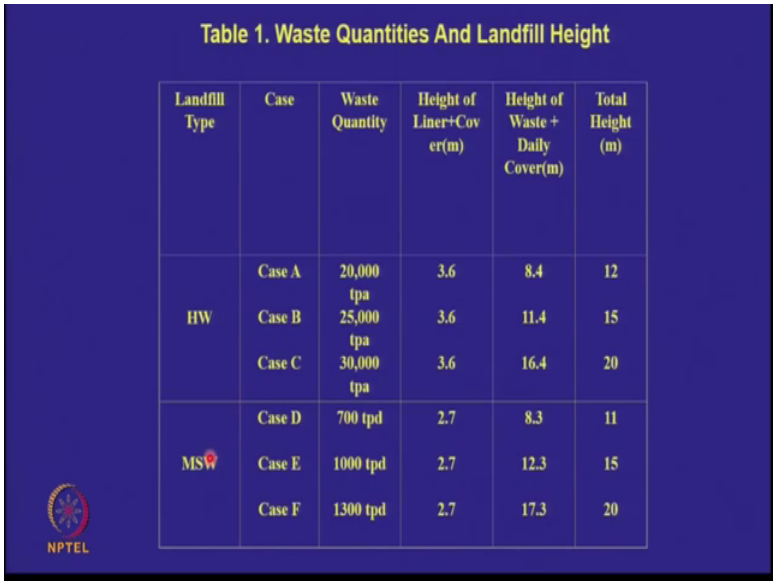

So, first look at the municipal solid waste landfill 1000 tons per day of waste coming in total height of the landfill was 15 meters out of which the liner plus cover would take 2.7 meters and the balance 12.3 would be taken by the waste and daily cover . Ad at the thumb rule your daily cover may be 10 percent of the waste. So, remember that the total height of the landfill is 15 meters 2.7 has gone into the liner cover that is why people keep wanting to make the liners and covers thinner and thinner. If you put a geo synthetic clay liner instead of clay you will get a meter or 90 centimeters if you put a geo composite drain instead of sand you will get 30 centimeters know. So, everybody wants to make this thinner and thinner, but we are going to look at this case and if 700 tons per day comes in on to the same area the height is about the 11 meters and if 1300 comes in its, but 20 meters.

So, here the base area is 800 meters by 800 meters whereas, here the base area is 220 meters by 220 meters, here its tons per annum, please see this is tpa and this is tpd the amount of hazardous waste which comes out is normally much smaller than the amount

of municipal solid waste which comes out in any urban area. So, here we are talking of hazardous waste landfill the height of liner and cover is gone up from 2.7 meters to 3.6 meters you can go and look back at the components and here the base case is 25000 tons per annum, 15 meter will be the height, 11.4 meters for the waste and daily cover at 3.6 for the liner and cover.

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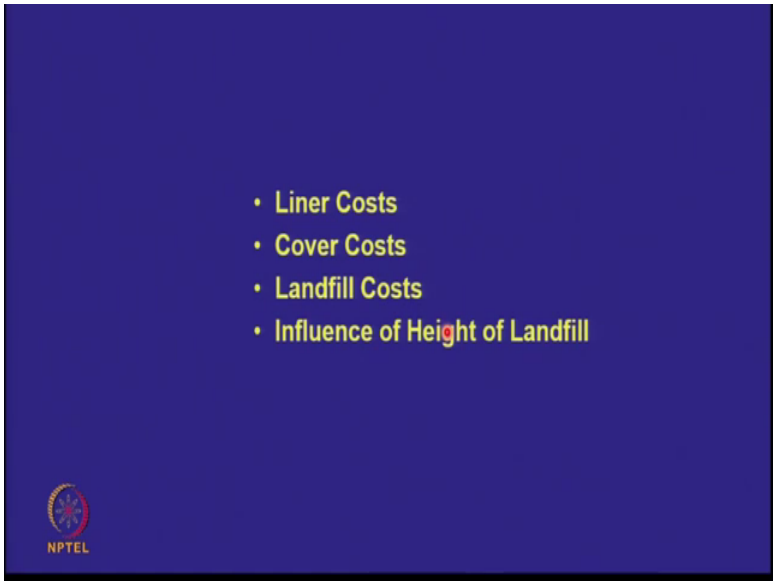

We are going to look at liner costs cover costs landfill costs and influence of the height of landfill.

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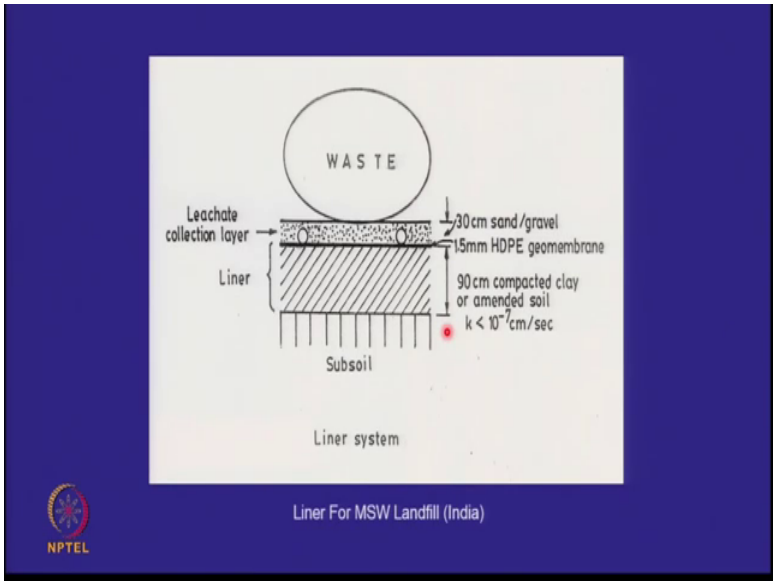

Let us just recall this is our liner for a municipal solid waste landfill thickness is 0.3 plus 0.9, 1.2 plus other elements.

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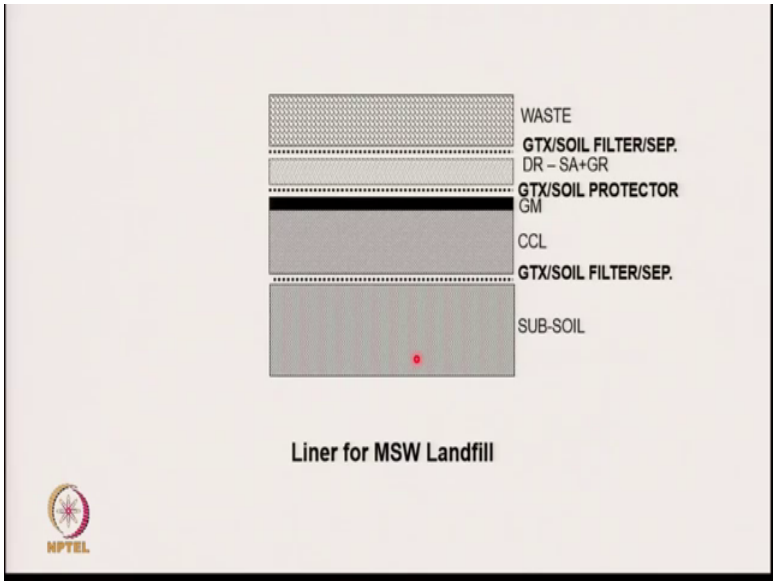

If you look at it very closely it is going to have many more components a separator filter the Leachate collection layer, a protector, the geo membrane, the clay and a separator filter so many many layers.

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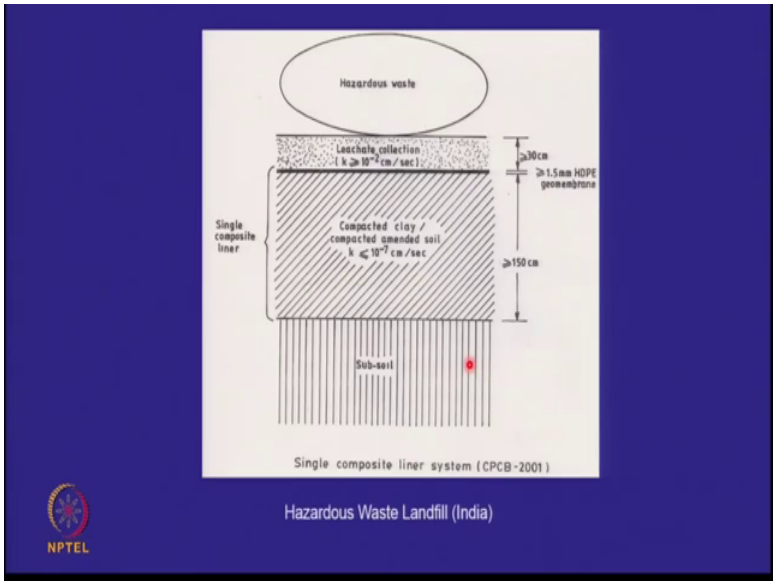

If I look at the hazardous waste landfill this becomes even more thicker this is 1.8, 0.3 here 1.5, 1.8 meters just at the bottom if it is a double composite liner there are even more elements.

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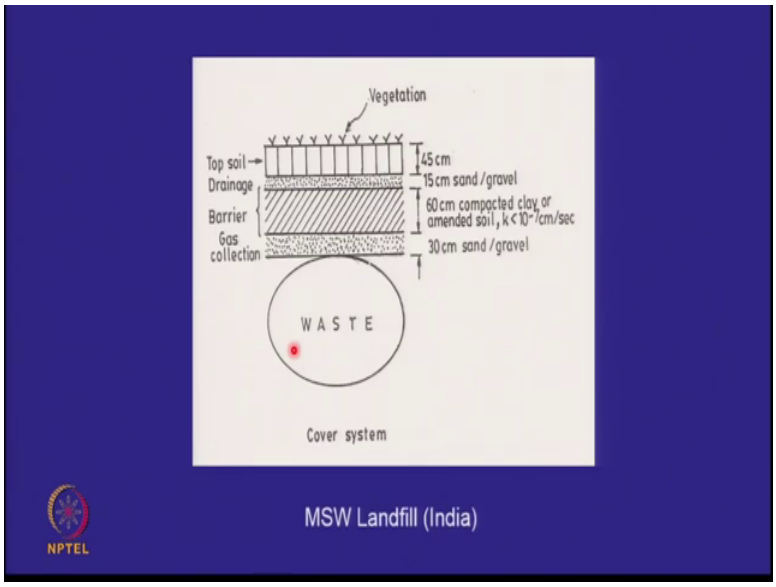

Similarly, if you look at the cover in the municipal solid waste landfill 45 sense 0.45 and 0.15 and 0.6 and 0.3. So, this whole total becomes 1.5 meters right 1.5 at the top 1.2 at the bottom makes a 2.7 meters which is saw in the table that I had shown you, if you have a hazardous landfill 0.6 and 0.3 0.9, 0.6 and 0.3 0.9 that becomes 1.8 meters at the top for the cover. So, out of the 15 meters 1.8 meters is been taken by the cover and similarly 1.8 meters is been taken by the single composite liner and again in the cover you have many many interfaces and if you are trying to recover methane gas as well then you have to put a geo membrane. So, this becomes the cover for municipal solid waste landfill also and hazardous waste.

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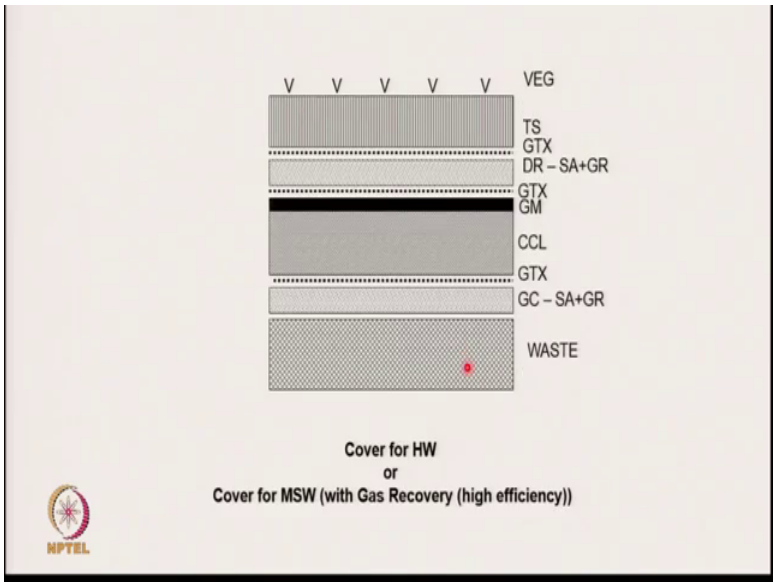

But remember in municipal solid waste landfill the thickness of the elements is different from the hazardous waste landfill.

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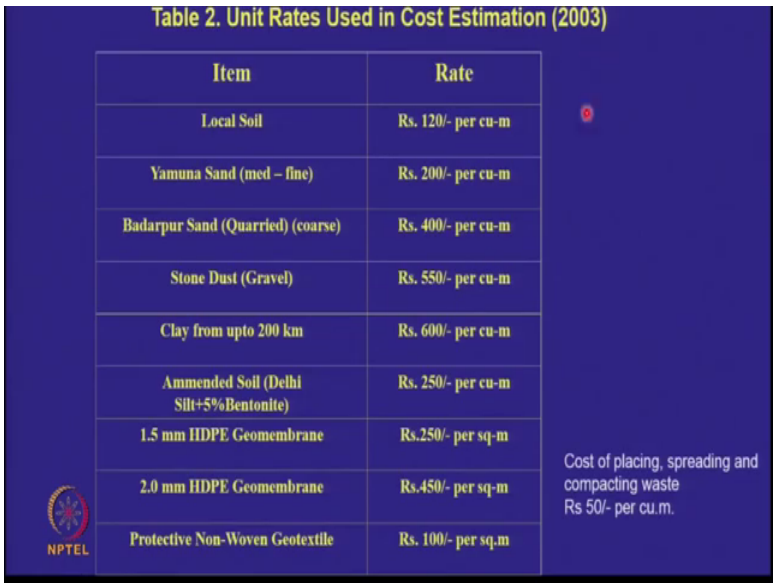

So, to estimate the cost you need to know the cost of materials. So, in 2003 when this exercises was done the cost of placing spreading and compacting the waste was 50, rupees 50 per cubic meter, is like a huge earth work problem you understand this earth works you want to make an embankment how do you pay the contractor you have to construct an road embankment from here to merit 5 meters high how will you work out

the cost of the project. Fundamentally it will be the cost of earth you will find out the volume of the earth multiplied by the unit rate at which the earth is available at which it can be transported at which it can be placed with compaction and you multiply and you will get a value.

Same thing here the waste is been once the place arrives which is brought to the site you place it you spread it and you compact it and the cost of it is 50 rupees per cubic meter. If you have local soil which you are going to use as the top soil the rate is 120 this 2003 please note how many years ago fourteen years ago. So, these are the rates at that time medium fine Yamuna sand 200 rupees per cubic meter. Badarpur sand 400 rupees per cubic meter this is coarse sand, gravel 550 rupees per cubic meters, clay from 200 kilometers 600 rupees per cubic meter amended soil Delhi silt plus 5 percent Bentonite 250 rupees per cubic meters then all these are in cubic meters because this is earth work and everything here is a square meters because these are a planar geotextiles which come from a factory, 1.5 mm HDPE geo membrane 250 rupees per square meter. So, I am giving you an idea of what they cost you in 2003 I will also give you the values today.

Just before coming to this class instead of looking at CPWD manual because they may not have everything regarding geo membranes and geo textiles in their unit rate are hang up civil contractor friend of mine and I said look I am going to give this lecture today I need the latest rates on this and then I will look at it a little later. But let us see what this study through up.

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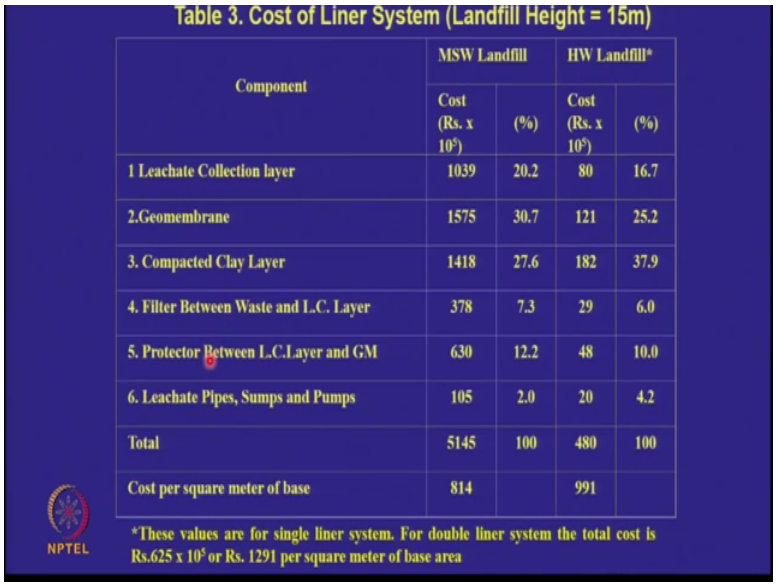

Now you want to do the costing of a liner system you know the thickness you know the areas you may you work out the volume of material required. So, if I look at the liner system I would have a Leachate collection layer I would have a geo membrane I would have a compact clay layer then I would have a filter between the wastes and the Leachate collection layer a protector between the Leachate collection layer and the geo membrane and some pipes and some sumps and pumps.

So, these are the quantities multiplied by the unit rates for the municipal solid waste landfill and these are the quantities multiplied by the unit rates for the hazardous waste landfill. This is 800 by 800 square they might have wastes which is coming much larger this is 220 into 220 meter square. So, you get some figure at the end which you can convert into the cost per square meter just like we have the cost of construction per square foot and the figure which comes out for a liner system here in 2003 when the landfill height of 50 meters was 800 rupees, 800 rupees for municipal solid waste per square meter and 900 rupees for.

Student: (Refer Time: 15:02)

Hazardous waste, but this is single composite liner if you go to a double composite liner it became about 1300 rupees per square meter separately listed here. So, remember the geo membrane and the Leachate collection layer and the compact clay layer at the main components of this costs. Let us now look at the cover costs.

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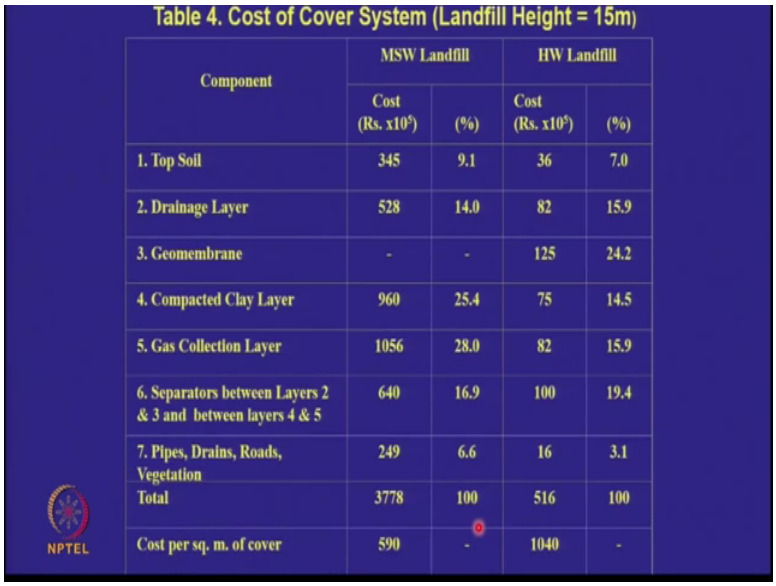

Now, you are become experts top soil then drainage layer then geo membrane then compact clay layer here in the municipals solid waste you do not have this geo membrane. Gas collection layer, separators this layer and that layer and this layer and that layer similar it what we did at this cost comes 590 for municipal solid waste and 1000 for hazardous waste, is this more than the cover or less that the liner or less than the liner you remember what is the cost for the liner.

Student: (Refer Time: 16:01) 800.

About 800 and this is about 600 and the reason is there no geo membrane in it should put a geo membrane in it what will happen the cost of go membrane are shown you I think is 250 rupees per square meter 250 will get added on to it. So, that the cover is no cheaper than the liner first you please remember that, specially if you trying to extract methane gas. Look at the hazardous landfill what is the cost here and what is the cost of the single composite liner.

Student: 990.

990. So, that is the same cost simpler cost similar cost are emerging. Then let us look at the total landfill costs and see what is the contribution of the cover and the liner to it there is a site acquisition cost. So, I told you do not take land cost do not mostly for these projects the government will give these at nominal value because either there will be

shelf operating the landfills; that means, palace even if they give it to an operator you cannot sell it at a commercial value it is you are wasting my waste, if you give it an operator you will charging for the land he will charge us back at the tipping fee point. So, some site development costs, site assessment, site development, roads and everything then liner and Leachate collection operation waste placement and final cover just see that figures here both on the municipal solid waste landfill site and the hazardous waste phase landfill site these are gross figures not per square meter which we did earlier will convert the whole thing into square meter.

So, there is some site development cost, but the liner and Leachate collection is higher waste placement this is of 15 meters high. So, this is the cost of placing 15 meter high waste at fifty rupees per cubic meter and this is the cover. So, do see that the liner and the cover have a significant role to play in the cost of a landfill.

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Table 5. Cost of Landfill Components and Total Costs of MSW and HW Landfills
(Landfill Height = 15 M)

Component	HW Landfill		MSW Landfill	
	Cost (Rs. x 10^5)	(%)	Cost (Rs. x 10^5)	(%)
7. Post Closure Care	180	9.0	750	4.0
8. Sub Total	1561		13813	
(Contingencies, Emergency Fund, Operator's Profit @ 30%)	468	23.0	4144	23.0
Total	2029	100.0	17957	100.0
Cost per Unit Weight (Rs/ton)	507		309	

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What is this percentage cost of the total? This table will continue forward.

What is this percentage cost of the total? This table will continue forward. Let me finish this there will be cost for post closure care and then there will be contingency is emergency operators profit all that. So, in a sense you get a value of the costs and you can see which component contributes how much to the total cost and I am going to go back and show you that the final cover and the liner cost contribute about 40 to 50 percent of the total cost of a landfill. It is like saying in your house the floor slab and the

roof slab contribute to more than 50 percent of the total cost, everything else belongs to the walls in the plumbing and the electricity ducts and everything else. So, 1 more than 50 percent sorry 40 to 50 percent of the cost in this study a cruise to liners and covers; however, if I increase the height of the waste instead of a 15 meter land fill on the same plot if I was to make a 30 meter high landfill what will happen.

Student: (Refer Time: 19:31).

The cost of the waste will go up this 195 will become 400 now it will become double because you have double the high then the contribution of the liner and the cover will go down. So, one important thing is height of the landfill plays a significant role as far as height of the landfill plays the significant role as far as the percentage contribution to the cost of land filling is concerned. You make a very thin landfill you make a 7 meter high landfill how much is it going to how much is going to going to the liner and the cover 3.7 and 3.6 further 10 percent is going to go into the cost of daily cover [FL] very little waste is placed.

So, if you want to have low impact of the cost of liner and cover do not make low height landfills make high landfills because neither is the liner going to become nor is the cover going to become thicker if you go higher are you understanding what I am saying therefore, the percentage contribution of the landfill liner and cover go down it is like. If you have cost of land you want to share it amongst more people please make your building higher and the cost of land will become shared by more people also per square meter I think it is not shown here, but the hazardous waste landfill is costing us 2000 lakhs and what was the area of this landfill yeah 220 by 220. So, you can figure out what is the cost per unit area can somebody do this quickly for me.

2029 into 10 to the power of 5 divided by 220 into 220 or you can, somebody can do it approximately for me 2000 into 10 to the power of 5 divided by 200 into 200.

Student: (Refer Time: 22:07).

So, 5000 rupees per square meter is the cost of your landfill if it is 15 meters high. Just check for the municipal solid waste how much does it work out 17957 divided by 800 into 800 I do not know somebody will check it out for me it will be cheaper.

Student: (Refer Time: 22:34).

So, one is 5000 one is 3000. So, that is the cost in 2003. So, let us see whether we can now do what it cost today, but before we do that I just want to bring you this picture. So, the important thing for you to note is if you divided by the waste weight of the waste inside the land fill then the cost of land filling is 500 rupees for ton here for hazardous waste single composite liner and it is about 300 rupees per ton here for municipal solid waste right. So, you can understand what is the cost of landfilling per ton of waste right.

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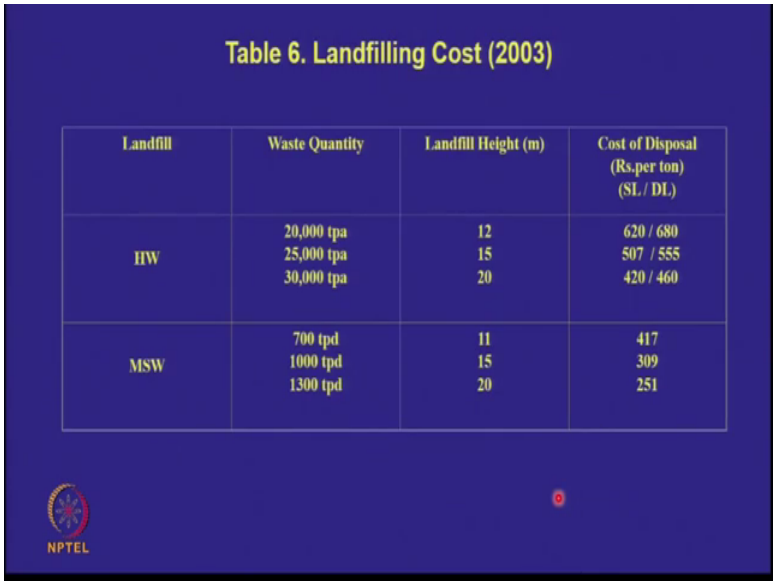

Now, I had taken municipal solid waste 1000 tons per day 15 meter high and my value is 309. If I make the landfill height 20 meters then the cost of disposal is to 250 rupees per ton, but if I make it of lower height the cost goes up. So, what we are trying to say is that as the height of the landfill changes the cost of disposal per ton goes down because the contribution of the liner and the cover goes down right. But do remember that you landfills are going to cost between 3000 to 5000 rupees per square meter at 2000 values agreed.

Similarly, here you will find the same thing for 15 meter high single composite liner the landfill was 500 rupees per ton and for double composite liner it is 555 per ton. Do not read this as a absolute values different cities will have different cost of materials if topsoil is 120 here, it will be 200 somewhere else if sand is 300, here it maybe 700 somewhere else. So, this is not across the country.

Now let us do a simple method for estimate of cost of liner and cover. Cost of liner and cover if you recall correctly was for hazardous waste landfill was almost 1000 900 1000 1000. So, both landfill cover plus landfill liner for the hazardous waste together would be 2000 rupees per square meter and the total cost was 5000 rupees per square meter showing that about 40 percent of the contribution of the landfill is from liners and covers.

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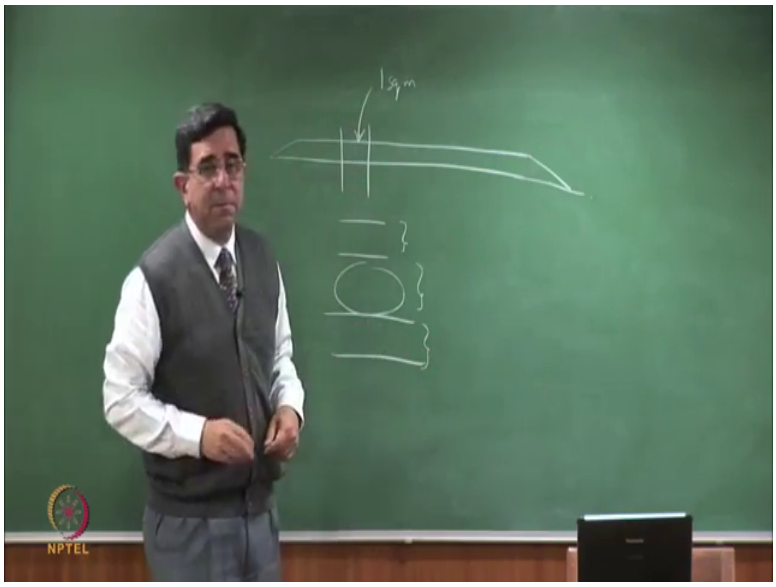

Now, let us come to today right and let us try and see can we do this simply and all I am going to says is if this is your landfill and I am often told you landfills are like this we make them very various strange ways in various books, but more or less landfills are thin and broad. So, let us take 1 square meter right and then I look at 1 square meter I am going to have a cover then I am going to have the waste and then I am going to have the liner agreed. So, already I got a do if I give you the unit rates if you know the thickness and if you know the rate per square meter of for geo synthetic you can compute the cost of this the cost of place in this and the cost of place in this. And if you add this, this should be about 50 percent of the total cost that should you done, but we would get an idea as to what is the current cost per square meter agreed.

So, let us look at the simple method, first let us look at what is happened to costs.

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In our first 2003 example there was no computation of there was no computation of what the of; how much does it cost to make grass go at the top because all landfills must have a green top. Now we have a handle on it having done 4 5 landfills across the country over the last 50 10 years today if you want to get an outside contractor to plant grass at your landfill and establish it in three months he charges you rupees 80 per square meter right. Local top soil is typically not available, but if it is getting excavated somewhere and you want to use it, it may be available to you at 200 rupees per square per cubic meter. Otherwise you will debug your own soil from the landfill.

If you want to use the local top soil right medium to fine sand in Delhi is now available at 500 rupees per cubic meter coarse sand and gravel is available at 1500 rupees per cubic meter clay from 300 kilometers available at 2000 rupees per cubic meter.

The HDPE liner today is three 150 per square meter and the non woven geotextile 200 GSM is rupees 100 per square meter and 400 GSM is 200 per square meter. We are going to use the thicker geotextiles in the bottom liner area because the overburden stress is very large and we can use the lighter ones at the top though I do not agree with it, but still people are using the lighter one.

Additional data which you are seeing to Leachate treatment cost about five rupees per liter and waste placement and compaction now costs about 100 rupees per cubic meter with this data let us design this.

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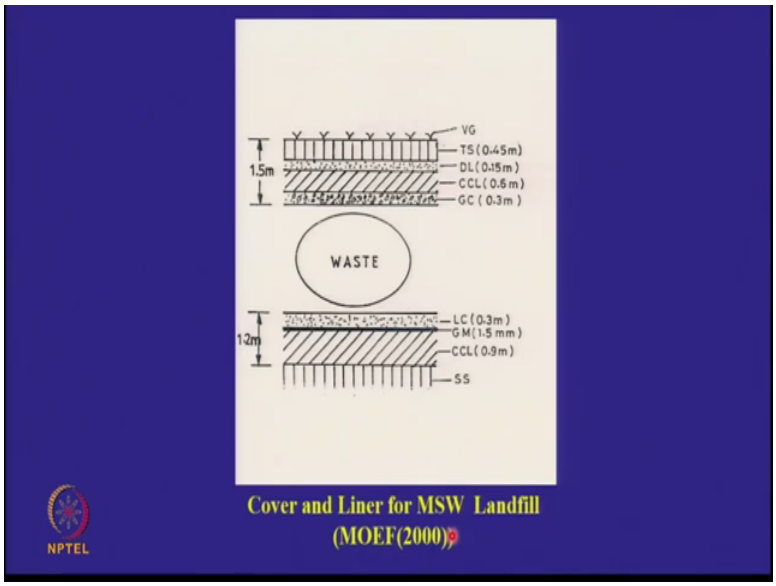

So, I want you to recall the cover is 0.45 the drainage level is 0.5 the compacted clay liner is 0.6 and the gas collection layer is 0.3 Leachate collection is 0.3, geo membrane is 1.5 compacted clay liner is 0.9 and we will have the various interfaces and I am going to use this example except that also introduce the geo membrane because I want to recover the gas. If I do not want to recover the gas then I do not geo membrane, but if I want to recover the gas I will put a geo membrane here and therefore, these are your interfaces cover.

So, let us just quickly tell me what are the elements if I come down the cover I need to put the cost of vegetation followed by.

Student: (Refer Time: 29:42).

Pardon.

Student: (Refer Time: 29:43).

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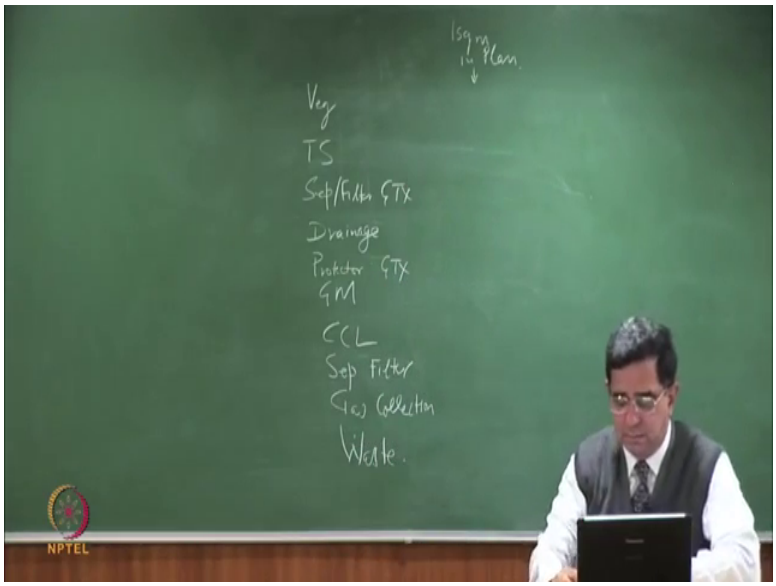

No there is in between, no there is vegetation topsoil then I have a separator filter which will be a GTX for me, then sand drainage layer I will put a drainage layer you will have to decide what you want to use, then.

Student: (Refer Time: 30:05).

No, then protector its again a GTX, then geo membrane, then compacted clay liner, then separator filter, then gas collection layer and then the waste. Now once square meter and planned I wanted to fill this costs for me here you need the unit rates I will bring the unit rates slide back do you understand what has to be done yes or no.

Student: (Refer Time: 31:04).

You take a square meter of plan area and tell me the cost of all the elements per square because you want in the end the cost of the cover and cost of the liner per square meter right. So, the first one will be 80 because that value is given per square meter it is not per cubic meter. So, that will be the cost of developing one square meter of grass. What about the local topsoil, how thick is the local topsoil.

Student: 0.45.

0.45 if you do not remember I will show you again, its 0.45 if it is 0.45 and the rate is 200 how much will be the cost.

Student: 90.

90.

Student: (Refer Time: 32:07).

[FL] cost is per cubic meter your planned area has 1 square meter your depth is 0.45 meter, so the out of material required is 0.45 cubic meter 200 rupees into 0.45 will give you 90 rupees you will not use medium med and fine sand please you will all at all the places we using the coarse and gravel. So, again to remember that the drainage layer is 15 in between will have the geotextile, does everybody have this.

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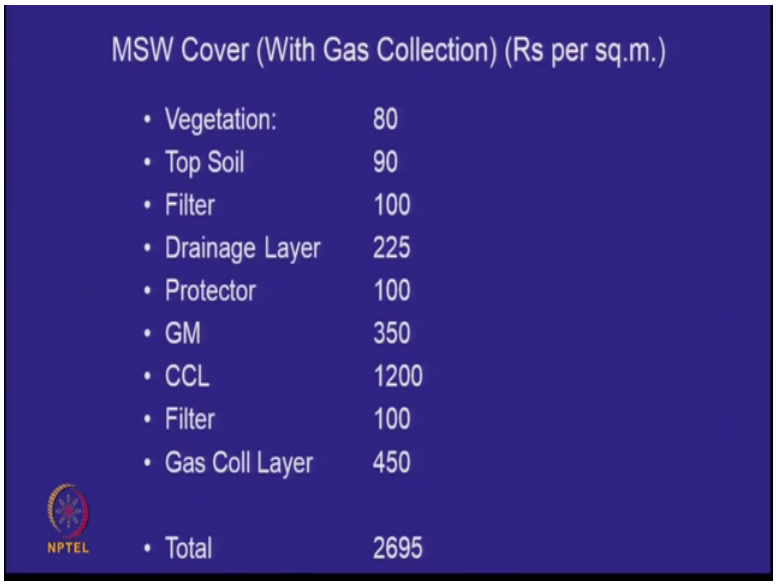


200 into 0.45 100 GSM, 0.15 into 1500 100 GSM, 350 2000 into 0.6 100 0.3 into 1500, the total cost of the cover per square meter is now almost 2700. What was it in 2003? We are done it in the slide earlier it was much lower than this.

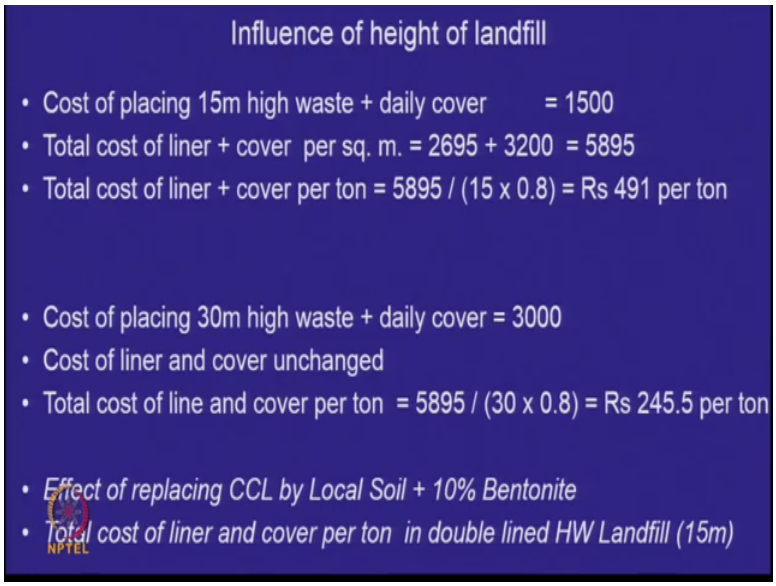
Student: (Refer Time: 33:10).

I will go back and show it to you, this is the cost of the liner system for the municipal solid waste landfill the cost of cover per square meter was 600 rupees and now it is as per the rates which I have given you 2695.

Similarly, I can do the calculations for the liner, similarly I can do the calculations for the liner and for the municipal solid waste landfill the liner cost is about 3200. So, if I now at

the liner cost to the cover cost how much does it become 2700 plus 3200 is how much. So, it is about 6000 rupees per square meter for the liner and cover. How much does it cost for you to make a house? 6000 rupees per square meter approximately 600 rupees per square feet right.

(Refer Slide Time: 34:15)



From this we can observe that the cost for ton works out to be 491 per ton, this is evident from the competitions in the first three lines if we double the height this cost falls to 245.5 per ton.

So, all that we are trying to say is it is about today 6000 rupees per square meter for a liner and a cover and if these are 40 to 50 percent the total cost of a landfill becomes 12000 rupees and the cost of municipal solid waste disposal as per the rates and as per the size that we have done is about 491. If instead of putting 15 meter high I had put a 30 meter high landfill which we do not do because a visual reasons then the cost would have been lower because in the same area I would be accommodating much more waste. So, the cost is high because what is the one which is contributing the maximum in terms of.

Student: (Refer Time: 35:17).

Cost here please note in this 2695 1200 comes from the clay in this 3200 1800 rupees comes from the clay. Can I reduce it? The clays very expensive because I am bringing it from 300 kilo meters. What will happen if I replace the compacted clay liner by local soil

plus ten percent Bentonite? What is the cost of local soil? 200 rupees. What is the cost of clay? 2000 rupees. What is the cost of local soil plus 10 percent Bentonite. Bentonite in the market comes in bags like cement it is used as a drilling fluid and it costs approximately the same as cement a bag of cement which is about 50 kilo grams will cost you about 350, 300 or 350 rupees. You can Google it up find the value of cement in Delhi to the nearest 50 and use that computation, what is the effect of replacing the compacted play liner by local soil and 10 percent Bentonite right and that cost will be much lower because it 2000 will be replaced by a much lower value. The total cost of liner and cover per square meter and per ton if I had a double lined hazardous waste landfill. Have you solve this example for a municipal solid waste landfill if I had a double lined hazardous landfill what will be the cost have a good day.