Urban Services Planning
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Lecture 35
Sanitary Landfill Design Part 3

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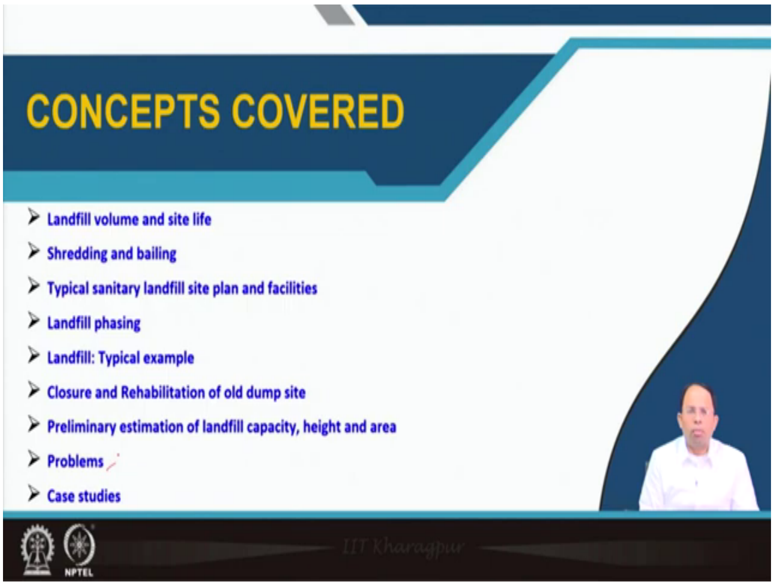

Welcome back. In lecture 35, we will learn about Landfill design Part 3 and here we will learn about determining the size of landfills. So, the concept that we will cover are on landfill volume and site life, shedding and bailing, typical sanitary landfill site plan and facilities, we will learn about landfill phasing, we will give a typical example of a landfill design, then closure and Rehabilitation of old dump sites, how to do that, then preliminary estimation of landfill capacity height, and area, and then we will show you some examples of problems, and then some case studies.

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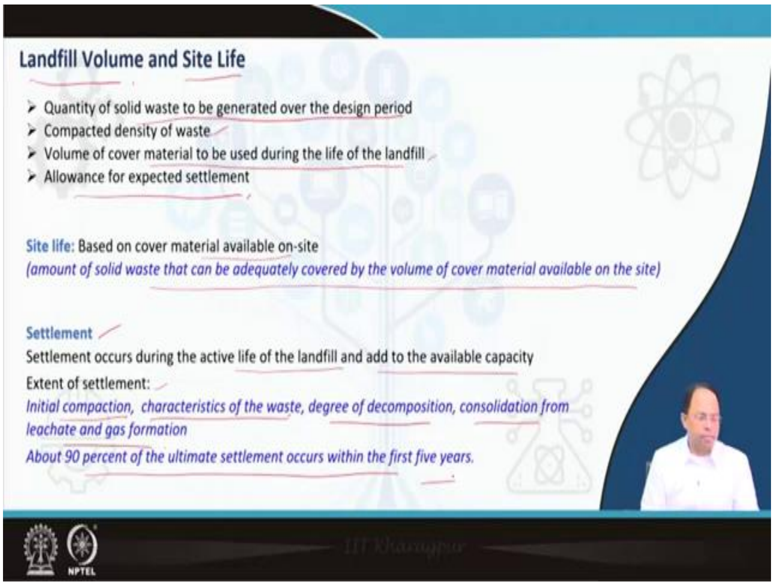

So, landfill volume and site life is what as a planner is most important that is what we need to determine, we need to determine the area that we require for that particular landfill, and that has to be determined for estimation of landfill volume. So, area of the landfill or landfill volume that has to be ascertain and also this will give us an idea about the site life of that particular landfill.

So, this is determined based on the quantity of solidness that is generated over the design period of the landfill sometimes we can design the design period based on land area available, alternatively, if I know that I have to have a landfill which will work for so many years. So, in that case we have to determine a land area or proper site where we have the adequate land area. So, in any case we have to estimate the total landfill volume or and the area required for it.

Then compacted density of waste for the kind of waste that is generated in that particular area, volume of cover material to be used during the life of the landfill, because as we have discussed earlier this sometimes determines the life of the landfill, if soil is not available it would be too expensive to import soil from outside.

Allowances for expected settlement, lot of settlement happens over the life of the landfill that has to be considered like we said that the average density is around 110 per meter cube, but during the initial life starting period it is 0.8 to 0.85 tons per meter cube, whereas in the final you will see around 1.2 tons per meter cube that becomes a density. The site life is based on volume of cover material or soil or the amount of solid waste that can be adequate covered by the volume of covered material available on the side. So, this could be 1 of the criteria for determining the site life of that particular landfill site.

Settlement occurs over the entire life of the active, during, it of course during the active life of the landfill and also later on as well to certain extent but less and it adds to available capacity of the landfill that means if the total volume is something because of settlement, we will have additional volume available that needs to be considered. So, the extent of settlement, how much settlement will occur depends on initial compaction, if the initial compaction is low then settlement would be higher.

Characteristics of the waste, if you have lot of organic waste and other material which decomposes and becomes gas and other breaks down into other materials, then of course compaction would be higher. Degree of compaction, how much I compact, consolidation from leachate and gas formation.

So, how much amount of leachate it is from, how much amount of gas is formed this also gives us an idea about what should be the settlement of the entire site. About 90 percent of the ultimate settlement occurs within the first five years. So, settlement keeps on happening over the life of the landfill and even after that but 90 percent of it happens during the first five years.

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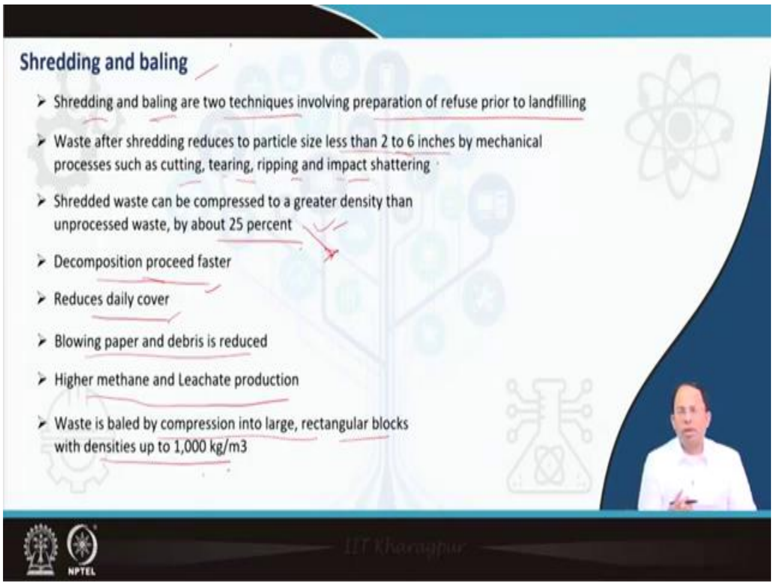

Then, we will talk about shredding and bailing, before waste is taken to a landfill site, we can further process it or we can reduce it or we can organize it you can say. So, shredding and bailing are these 2 techniques involving preparation of reviews prior to land filling. Now, if the waste is shredded, shredded means we make it into smaller pieces, we have discussed some of it earlier as well, and bailing means, compacting the waste into some volume, which is like maybe a rectangular block or a squarish block and with higher density. So, waste can be built by compression into large rectangular blocks with densities up to 1000 kg per meter cube.

So, that is how we can do first trading and then bailing which helps in organizing the waste in small in compact units which could be stored into the cells of the landfill side. Waste after shredding reduces to particle size less than 2 to 6 inches by mechanical processes such as cutting, tearing, ripping, and impact shattering. So, these are the mechanical processes that could be taken up to shred the waste into smaller sizes.

Shredded waste can be compressed to a greater density than unprocessed waste by about 25 percent. What it means? that means it will increase the capacity of the landfill by 25 percent if I adopt shredding and bailing. So, obviously that is in case in areas where we are, where land is very short or plant is available only at a very high premium we can go for shredding and bailing of waste.

Shredding also because we are making it into smaller pieces and all it allows helps in decomposition faster, it reduces the daily cover because there would be lesser things sticking out of the waste because everything is small size, so the cover could be given uniformly, so reduces the daily cover it reduces blowing of paper and debris from the waste, it also results in higher methane and leachate production because of more decomposition. So, that is why before even we bring the waste or we put the waste into the active landfill site, we can adopt this particular measures.

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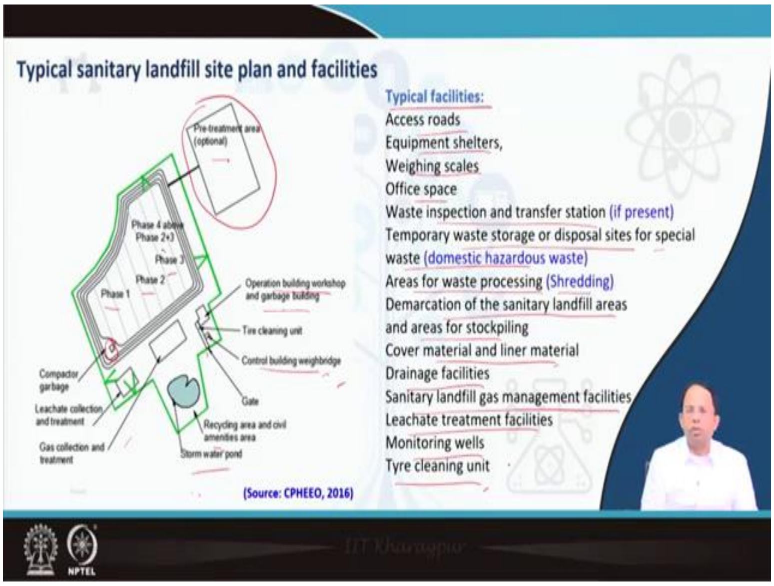

So, this is how a landfill site looks like. So, just you can see there are phases, phase 1, 2, 3, we have discussed spaces earlier but we will discuss it further. So, these phases are designed that means the entire volume that is required to be, obvious that is in the volume of ways that needs to be stored in the landfill that happens over a period of years.

So, we design each phase maybe for 1 or 2 years each phase. So, we only work with that part of the landfill. So, as you can see these are the phases of the landfill, then there are pre-treatment areas if I want to do some sort of sorting of the waste some amount of recycling that could be done. So, that is a pre-treatment area. So, it is a big Centre over here.

Then we could use a compactor. So, that which before we put in the garbage, we can first compact it and then we can put it inside. So, that is why we can install a compactor over here. Then, we have a leachate collection and treatment system, a gas collection and treatment system, a storm water Pond which is required for surface water management, and we have a Control building, way bridge for the weighing the particular vehicles, there is an entry gate there is operational building, workshop, where repair repairs could be done garbage building some sort of other pricing could be done and so on.

So, typical facilities within a waste landfill site typical facilities within this landfill Site Area includes access roads, equipment shelters, weighing scales, office space, waste inspection and transfer station, temporary waste storage or disposal sites for special domestic hazardous waste maybe areas for waste processing may be spreading of waste, demarcation of the sanitary landfill areas and areas for stockpiling where we can stockpile some amount of material.

Like cover material, cover material and liner material storage, drainage facilities, sanitary landfill, gas management facilities, leachate treatment facilities, monitoring wells, Tire cleaning units for the waste collection features, because once it moves out of the site, if the tire is dirty it will keep on spilling the garbage in the normal Urban Roads that is not desired. So, that is why tire cleaning units are also installed. So, these are the typical facilities in the landfill site, landfill site is not only about storing of the waste or the volume required for Waste storage, but also several Allied facilities also needs to be accounted for.

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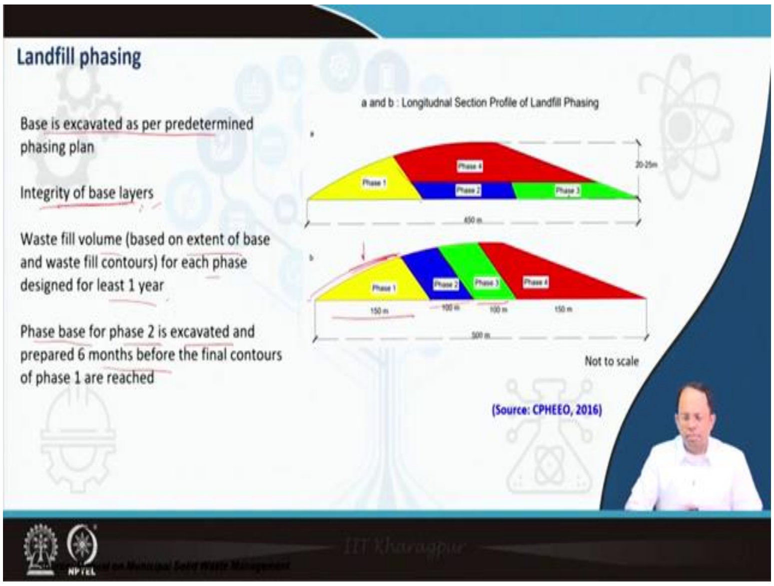

So, we have discussed that base is excavated as per the predetermined phasing plan. So, we have to discuss on the phasing of that particular landfill site and then accordingly the base has to be prepared. Now, because these phases are done not simultaneously one after another that but the bases are also, at the end of the day the basis has to be integrated, so that there is no leakage in between this two-base.

So, because of the 2 phases, we have got the bases which are constructed at 2 different time periods. So, there may be some gaps in between this, that should be prevented. So, Integrity of the base layer should be maintained and waste field volume based on extent of the base and waste field concludes for each phase designed for at least 1 year.

So, that means phases should be at least 1 year or sometimes it could be for 2 years. And phase base for phase 2 is excavated and prepared six months before the final Contours of phase 1 had reached. So, that means we have to prepare the next phase before even the first phase is, the previous phase is completed. And in this image, you can see the different ways phasing could be done the bottom 1 is very simple phase 1 we are giving a 3 to 1 slope, then the phase 2 is after that, phase 3 is after that, phase 4 is after that.

Why this is done this way? Because phase 4 will require separate sizes of cells. So, we have to design it separately, plus, because at the end of 1 year we can put a cover over here and protect this area, so that infiltration will not happen and we only work on this area, so this becomes the active phase or it could be done like this we do phase 1 like this, then phase 2 could be done in this order, and then phase 3 could be above top. So, there could be hundreds of ways we can do the phasing of a particular landfill site.

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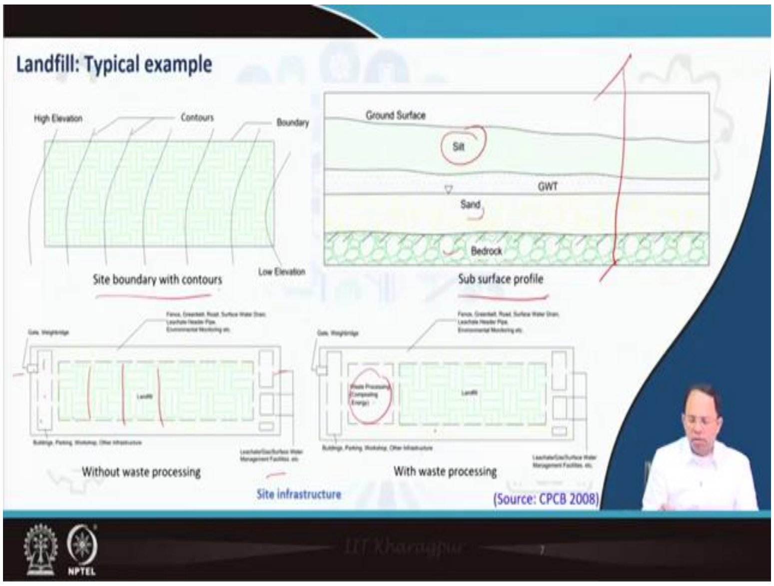

So, let us see a typical example of a landfill site. So, first we have to determine the southbound, the side boundary along with the contour lines of the site to understand, where we have to cut, where we have to fill and so on. So, we have to create the subsurface profile of the site. So, you can see this is the Bedrock maybe the soil layers above it maybe there is sand, then there are groundwater table we have to determine, then the layer of soil above it maybe there is silt soil over here. So, this is what needs to be determined and the entire profile or the section of the ground needs to be understood.

Once that is there, we are, based on the site we can determine, what should be the layout of the site like over here this is the gate, this is the way bridge, some buildings, parking, workshop, and other infrastructure could be put over here, this is the actual area of the landfill, this could be again broken up into different phases, and over here we have the leachate collection system, leachate collection treatment system, treatment area, the gas collection and treatment or energy generation area or surface water management facilities and so on, all housed over at this site. In case, the best processing and is happening like we can do some amount of composting or we do some amount of other sorting. So, in addition to the landfill area, we have a waste processing area also fit into the lateral site.

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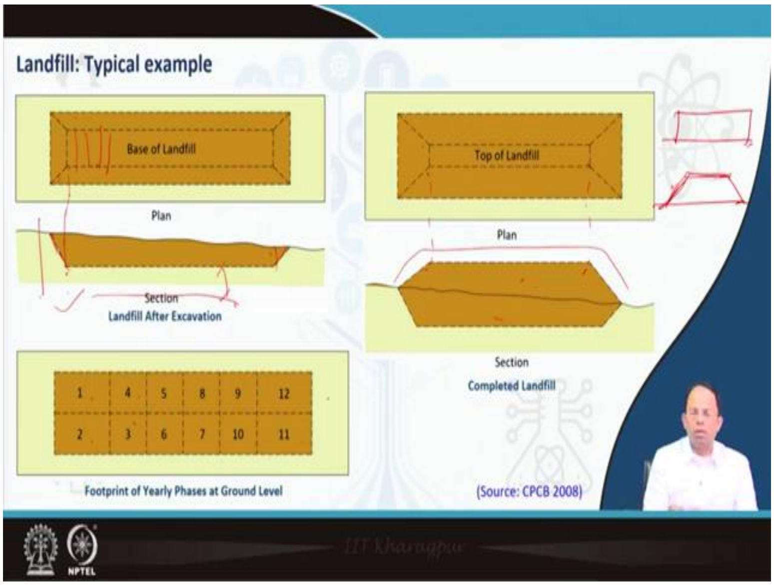

Now, this is how the, this is how, let us assume this is the section of the landfill the profile of the ground. So, we can, go a little bit below, maybe groundwater is available even below, we keep the maintain we maintain the minimum distance and we can dig up and we can go for a trench field initially, and then as we have discussed earlier most landfills are like a modified area landfill, over here you can see that eventually the landfill will look like this, some part below, some part above.

Now, the base of the landfill is given a slope like this, as you can see over here that is the bottom most part, the sides are sloped, this is the side, this aligns with this. So, this is the side slopes are given on all the 4 sides and the centre is the base is more or less flat. But of course, this again the base even though it is shown as a flat, the slope has to be given as per the drainage Network as we have discussed earlier.

Now, top of the landfill over here also it is not it is not a square box it is more or less like a pyramid; it looks something like this. Why? because we have to give a 3 to 1 slope, that Vehicles can go up as well as water can come down and usually the top is a relatively flat, that is what has been shown over here, this aligns with this. Now, this could be the phases of the landfill, again the phase design could be in many different ways we can do the phase design but let us assume the faces are done like 1, 2, 3, 4, 5, 6 and so on. So, this is how the phasing has been done.

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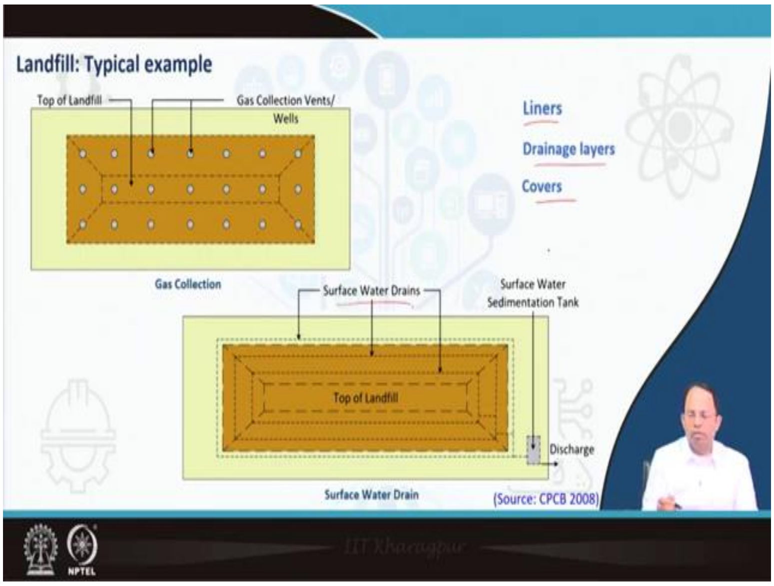

Now, once the landfill profile is designed then we can design determine that the gas collection Wells the placement of the gas collection Wells. So, this has to be predetermined we can design the the not only the gas collection system but also the drainage system and so on. So, those layouts could be designed earlier based on the profile of the site as well as the section and so on, the top of the landfill we can design the surface water drains at what height we will Design the drain. So, this needs to be predetermined, the liners, drainage, layers covers all can be predetermined when we design the landfill and before actual operation all these designs used to be finalized.

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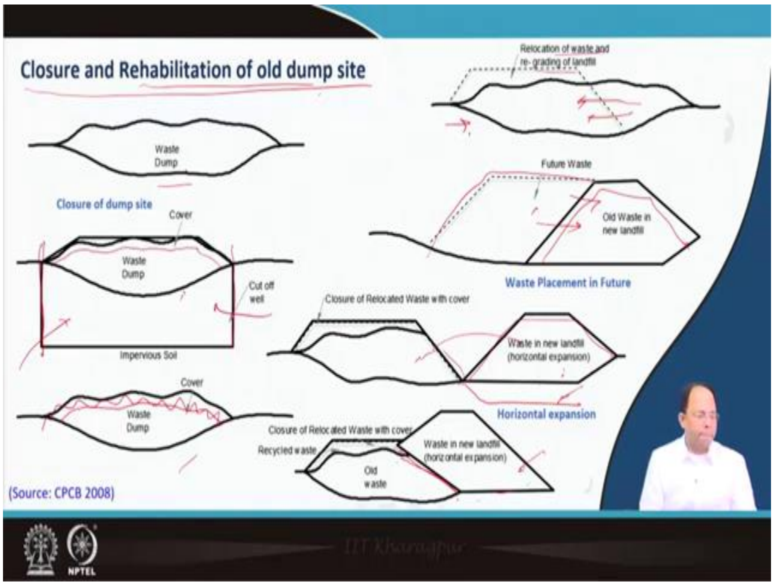

Now, in many cases and as per instruction says in the MSW, in the solid waste management rules 2016, we need to also close and rehabilitate all thumb sites, how we can do that? So, let us assume this is a waste dump which is there, how we can close it we can put a proper cover as you can see over here we are giving it a shape that we can put a proper cover on the existing dump site and here also we can put some impermeable barriers, so that we prevent groundwater to park come and mix with this particular dump site, so this is one way.

So, the other is to put a particular cover above the existing dump and then we are done with it, in other thing if this kind of things are not possible we can just put at least a proper cover at the top and then close it. Now, sometimes what happens? There is also we have to there is very we have discussed this earlier that there is limited amount of area available for landfills.

So, sometimes you have to work with the existing landfill sites which are maybe not properly designed. So, in that case what we can do is we can take a existing landfill site like this, we can relocate the waste, and we can regret the landfill, so this is how we can assume that this is going to be the design of this landfill, we can shift this waste to this side as you can see that we are moving the waste giving it a shape, we can put a proper cover on it and then we can have excess area available for future rest or in this case, you can close this existing landfill site like this some amount of waste groups relocated over here and we can have new waste, new landfill design, fully new landfill design at the side of the existing landfill.

Sometimes it could be also designed in this way where part partially it can rest on the existing landfill and partially it can be on the site of this particular landfill. So, this is how existing landfill could be also redesigned, re-engineered to take care of new waste and in a more better, more protected facility.

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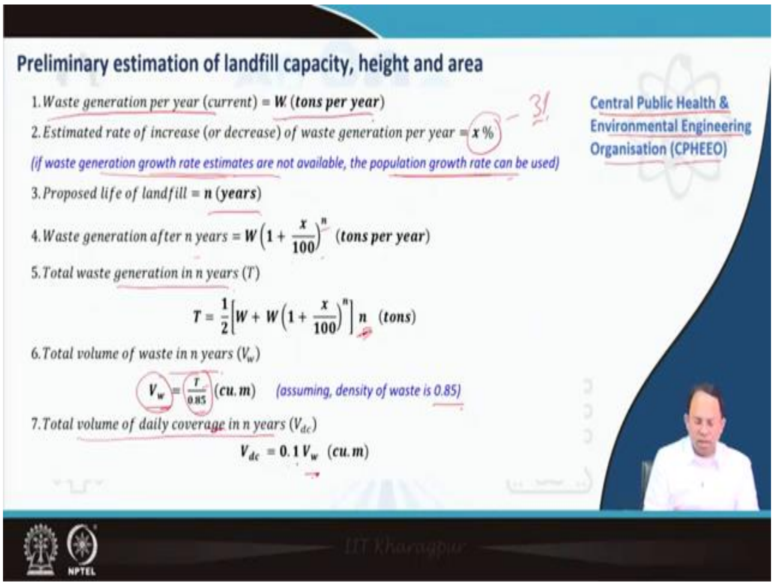

So, how do I calculate the total area required for a landfill site. So, that is what we have to do, but as you understand, that we cannot do very detailed estimate at the beginning, because we are neither aware of what sort of waste will eventually come in the future, we can make estimates, but we do not know exactly how much. what would be the condition of the site if something some natural Calamity has occurred. So, we need to modify our designs gradually over the life of the active landfill or over the life of the landfill site. But before we even start we have to determine where we should acquire land, how much amount of land should be required, we need to do some preliminary assessment.

So, to do that we have to follow certain steps, these steps are given by the central public health engineering, environmental engineering, organization CPHEEO, we can follow this particular steps. So, these are, first we have to determine the waste generation per year this current year this is in tons per year for this particular urban area and then we can assume in the rate of increase of this waste which could be 3 percent, 4 percent, whatever is the case may be, in case this waste generation growth rate is estimate is not there, in case the population growth rate can be utilized.

Now, as you can understand with more population, more waste will be formed, but that does not means that there that does not mean that exactly with growth in population the waste will also grow in the similar way, if the growth in population is of like certain income brackets grows more in that case other kinds of waste should be generated, that means waste generation growth has to be estimated on its own, if it is not there then only we have to go with population growth rate estimate.

So, proposed life of landfill, then we have to go with the assumption of the proposed light which may be n years. Then we also have to estimate that what would be the best generated at the nth year. So, that means at the rate of this growth may be 3 percent to 4 percent, 2 percent whatever it is, what should be the waste that has been generated in the inner tier of the like the landfill, why? Because the waste that is coming to the landfill will not remain same over the years, we have to account for that.

So, this is given by W into 1 plus X by 1000 to the power n, n is the number of years of the site life, this is the final year, this is the initial year, the total waste generated over the life of the landfill is half of W plus the final years waste multiplied by the number of waste, number of years of site. So, we take the average waste generated per year over this site life multiplied by the number of years of site like for this particular site. So, that gives us the total waste generation in NES. Now, waste generated is not the best volume that is required, it depends on the density of waste. So, first we determine the waste volume by dividing the total waste quantity of waste divided by the density of waste.

So, density of waste is assumed to be 0.85 tons per cubic meter, we divide that and we get around this the, this is the value which is the VW or which is the volume of waste in n years. Now, total volume of daily cover which would be required for this NES is at actually 10 percent of the total waste volume that we have discussed earlier. So, we take 0.1 VW is the total waste volume is VW, 0.1 that is 10 percent of that is what V DC which is volume of daily cover, not daily cover.

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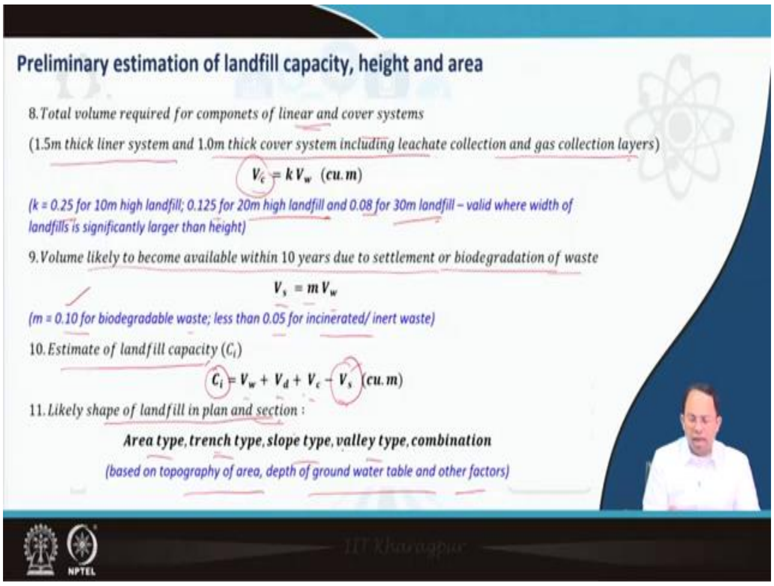

Then, along with daily cover we require components like liners, covers and so on, total volume that is required for that assuming a 1.5-meter-thick liner system, 1 meter thick cover System including leachate Collection gas, gas collection layers, in that case we can take another Point 25 percent for landfills are smaller height, if the landfills is of larger height this volume is lesser which is 0.125 means 12.5 percent or in case of 30 meter higher landfills, this is even lesser which is around 8 percent.

So, in most cases you can go it would be safe to assume a value of 0.25 and we can say that we require another 25 percent of the volume of waste as this sort of liners that are liners and covers that are required in a landfill site. Then these are all additions or in terms of volume but at the same point of time volume likely to be available within 10 years due to settlement or biodegradation of waste.

So, there is lot of organic matter in the waste which becomes which degrades and accordingly lot of gases are released and so on. So, there is lot of compactions that happens, at settlement of the waste that happens. Usually that is taken as VS equal to M into VW where the value of M is around 10 percent for biodegradable waste or 5 percent per incinated or inert waste.

So, in case there is lot of biodegradable waste we can assume that in most union landfills have got certain amount of biodegradable waste, we it is safe to go with 10 percent. So, that means 10 percent volume would be available due to compaction. So, total estimate of landfill capacity is CI equal to VW plus VD plus BC minus vs VS, so, vs is the additional volume that is available because of compaction, whereas these are additions, this is subtraction.

So, finally this is the total volume of landfill. So, this is the total landfill capacity that is required we have not yet estimated the area, it depends on the height of goods, but before we do that we have to understand the shape of the landfill that we will add up, and what would be the section of the landfill. How much of it is will be below ground?

How much of it would be above ground or is it just a landfill which is above ground will it be area type, range type, slope type, valley type or a combination of all this. So, based on topography of the area. depth of groundwater table and other factors we will determine what sort of shape we will. what sort of landfill we will go for, and based on that we have to determine the area.

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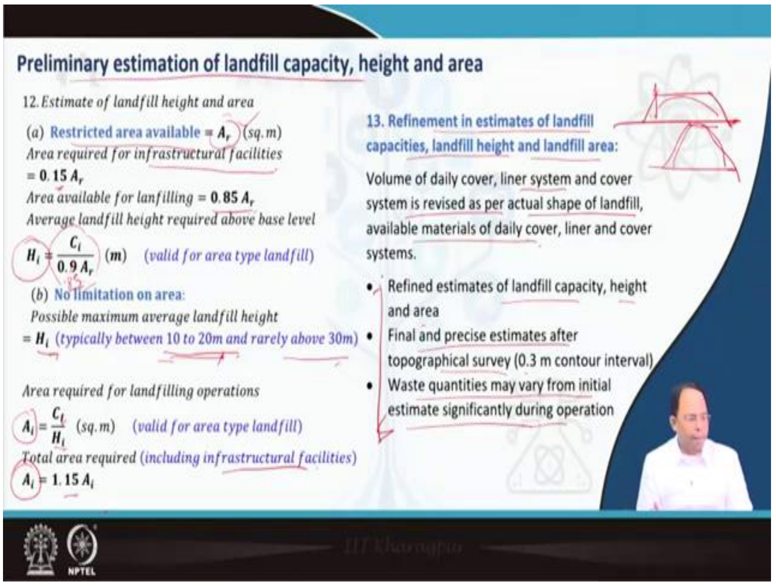

So, the first assumption is that that the area is restricted, that means we have a fixed area for the landfill side. So, we know, now know the volume of area that is required for the, this overall waste and, Allied material volume, covered volume and so on. So, to if, we can say that point fifteen percent of the area would be required for the infrastructural facilities or alternately, we can say 85 percent of the entire area of the site would be dedicated for storing of waste and covers and so on. So, we take only 0.85 percent of the total area which is available AR.

So, definitely the height of the landfill would be C1, which is the overall volume required divided by 0.85 AR, this would be 0.85 here, sorry, this is what we can take right or instead of 0.85, we can take a little bit more because of, compaction and all but we better go with 0.85. So, this is the height of the area that is required because it is not only about the waste but also some amount of, this cover and all these things will be at the top of it. So, the height would be a little bit larger. So, that is why it is taken 0.9, but we can again, that that depends on the actual design of the landfill side but we can it will be safe to go with divide by 0.85.

So, that means the height of the landfill site is determined if I know the area, but this is never the case, in most cases, we determine the area which is required based on the design of the height. Now, the height design is based on the profile of the section of the landfill, the groundwater table depth and many other factors, operational factors and so on. So, typically it is 10 to 20 meter and really sometimes it goes around to around 30 meters.

So, typically we have landfills around 10 to 20 meters. So, in that case the height is more or less fixed, we fix the height beforehand, there may be other aesthetic concerns and other concerns as well. So, in that case C 1, CI divided by HI, this is CI gives me the total area required for the landfill, now this area is just for the storage of waste. So, in addition radio required for infrastructure we have to add another 15 percent, which becomes 1.15 AI. So, this is the total area that would be required for the landfill site.

Now, as we, as you understand this is the preliminary estimation of the landfill capacity and that also a very very crude estimation I will show you some examples later, but if I need to do, the actual we need to refine these estimates of the landfill capacities using landfill height, the actual height that for that particular area and that considering the local context we have to define this particular estimates.

So, volume of daily cover, liner system and cover system is revised as per actual shape of the landfill, because if I go with a landfill which is like this, it will require certain kind of cover, if I go with a landfill like this, it will require another volume of cover, but for even though the overall volume remains same. So, this has to be re-estimated as per the actual shape of the landfill and also depends on available materials for cover liners available mid soil that would be used for this making these particular liners and covers

So, we have to do refine the estimates for landfill capacity height and area. So, final and precise estimates after topographical survey, this topographical survey is done at 0.3 meters Contour intervals and base quantities may vary from initial estimate significantly during the operation years. So, all this will lead to refinement of the landfill capacity over the years and we need to adjust accordingly.

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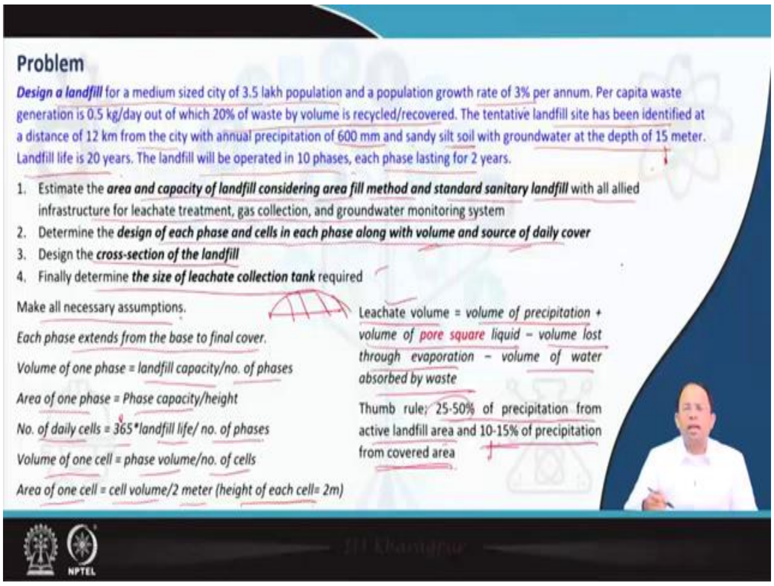

So, I will very quickly take you through a problem, just to give you an idea, again this is a, this is this will demonstrate how you can also calculate but this is not exact you can make modifications as per your case, but it will give you an idea about how to go about the process. So, let me first read through the problem, design a landfill for a medium-sized city of 3.5 lakh population, and the population growth rate is 3 percent per annum. Per capita waste generation is 0.5 kg per day out of which 20 percent of waste by volume is recycled or recovered, that means 80 percent of the waste goes to the landfill site.

The tentative landfill site has been identified at a distance of 12 kilometre from the city with annual precipitation of 600 millimetre and Sandy sealed soil with groundwater at the depth of 50 meters. So, that means groundwater is not an issue, that means groundwater is much much below. And the soil is sanity and sandy soil, Landfill life is 20 years, and landfill will be operated in 10 phases each phase lasting for 2 years, that is what has been given to us

So, what we have to estimate? we have to estimate the area and capacity of the landfill considering area field method and standard sanitary landfill with all Allied infrastructure for legit treatment, gas collection, groundwater monitoring system. Determine the design of each phase and cells in each phase along with the volume and surface at the source of daily cover, that means for each phase how much amount of volume, what would be the cell size in each phase, what would be the volume required what would be the amount of daily cover required, this has to be determined.

Design the overall cross section of the landfill and finally determine the size of the digit Collection Pack. So, these are the things that has been given to us. Now, few assumptions or few rules that has been given to us each phase extends from base to final cover. So, that means each phase would be done in this way, that means if I have a landfill site something like this, we do not do 1 above another, volume of one phase equal to landfill capacity divided by number of phases area of one phase, phase capacity divided by height of the landfill of course, number of daily sales 365 into landfill life divided by number of phases, 365 multiplied by landfill life into divided by number of phases. So, that will be the total number of cells required in the landfill. So, that every day waste comes in, that has to be considered, volume of one cell is equal to phase volume divided by number of cells.

Area of one cell equal to cell volume divided by 2 meters. So, that is given the height of each cell is given as 2 meters. Some, the leachate volume usually is depends on the volume of precipitation, volume of the poor Square liquid, the liquid that passes through the geotextile layer comes into the liquid layer, volume loss Revolution, volume of water absorbed by best, this is how the digit volume should be considered, but for thumb rule we can say 25 to 50 percent of the precipitation from active landfill areas and 10 to 50 percent of precipitation from covered areas becomes legit.

So, that means when we are walking on the landfill, that means we are pushing waste into the particular phase, in that particular phase operation is going on, in that particular area around 25 to 50 percent of the precipitation that pulse will go inside the land and why? Because we have only a limited soil cover like 10 centimetre soil cover at the end of each day's work right and also that would be intermediate, I'll cover on the areas which are not being worked for the next 3 months right but still lot of water goes in.

So, because there is no final cover given, but 10 to 15 percent of precipitation from covered areas, that is intermediate covered areas of final covered areas if they only have limited amount of water enters from those areas, that is around 10 to 15 percent, in case of final cover, this is even lesser. So, as you can understand it is very very complicated, it needs to be as per actual design actual state of operation, we need to design determine how much amount of precipitation is go will go inside this particular landfill site.

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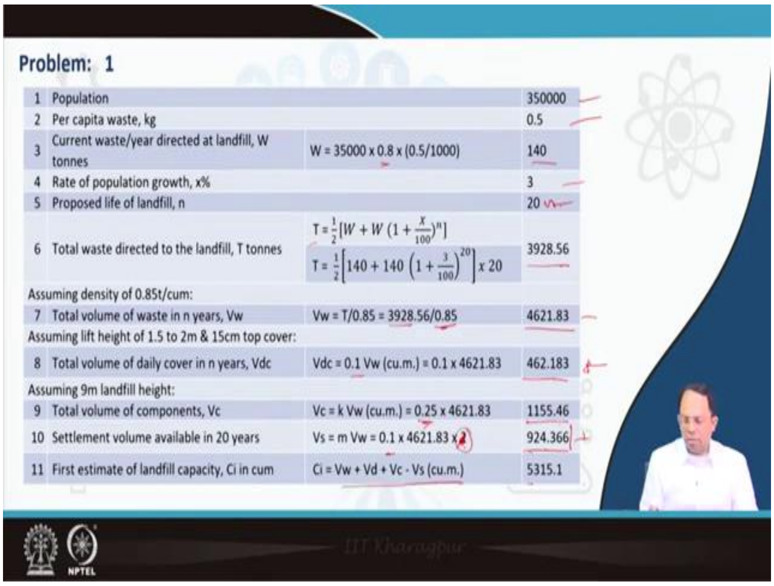

So, going into the problems, we will follow the same procedure given by CPHEEO, population is 3.5 lakhs per capita 0.5 kilograms per day, current waste per yard which goes into the landfill site, in tons, W tons is 80 percent because 20 is recycled. So, it comes to 140 tons rate of population growth 3 percent, proposed landfill life is 30, 20, which is n. So, we can determine the total quantity of waste that is generated which comes to around 3928 tons of waste.

Now, total volume of waste is in 8 years which is this total unit tons of is divided by the density which comes to around 4621-meter cube of waste is generated. Then, assuming lift height of 1.5 meters to 2 meters and 15-centimeter top cover, we can say that total volume of daily cover comes to around 10 percent, which is 462, here you can determine the quantity of soil cover that is required and the volume of soil that is required, 462-meter cube of soil, total volume of other components of liners is 1155-meter cube of soil, which is 25 percent has been adopted.

Then settlement volume 10 percent, and because there are 2 phases it is multiplied by 2 because, every 10 years set to be can estimate settlement, but you can ignore this 2 in that case it would be half of this which should be available, but anyway you can also create a little bit, consider a little bit higher settlement as well because it is for 20-year period. Final estimate of landfill capacity is as per the formula given earlier which comes to around 5315 cube meter cube of this space that is required.

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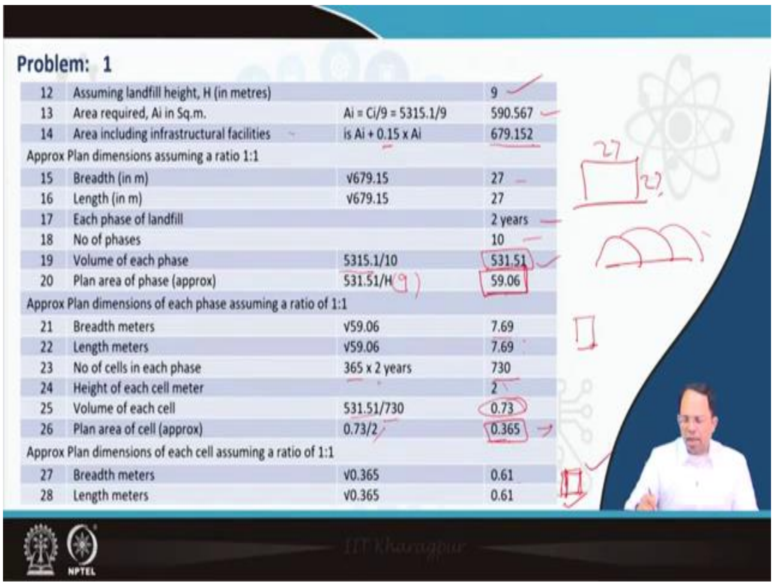

Now, height is given which is 9 meters. So, area required would be total volume divided by 9 which is 590 square meters infrastructure facilities another 15 percent, it becomes 679 square meters. So, the total breadth of the landfill is, if I take a squarish landfill site, it comes to around 27 meters by 27 meters.

Each phase is for 2 years, number of phases is 10, we determine, divide the volume of each phase, like total volume is 5315 for waste divided by 10, this is the volume for each phase. So, plan area of each phase is also then divided by 9, H is 9, because each area has been done and then we move on to the next area, that is 59 square meters is the area of each phase, because the area is 59 square meters we can say the size of each phase again, if I consider it as a square around 7.69 square meters for each length and breadth of each phase.

Total number of cells, because it is for 2 year period, 365 into 2, 730 height of its cell is 2, volume of each cell is, this is the volume of one phase divided by 730, so this is the volume of each cell and we divide by 2 we come to around 0.365 is the total area of itself. And because it is 0.365, we can say if I consider a square cell each size is each direction is 0.6 meters, so that is 2 feet by 2 feet is 1 cell. So, this is a very, this shows you a very crude way to estimate the cell size eventually but at the same time if of course the waste volume increases, the phase volume increases, automatically the cell sense will be larger.

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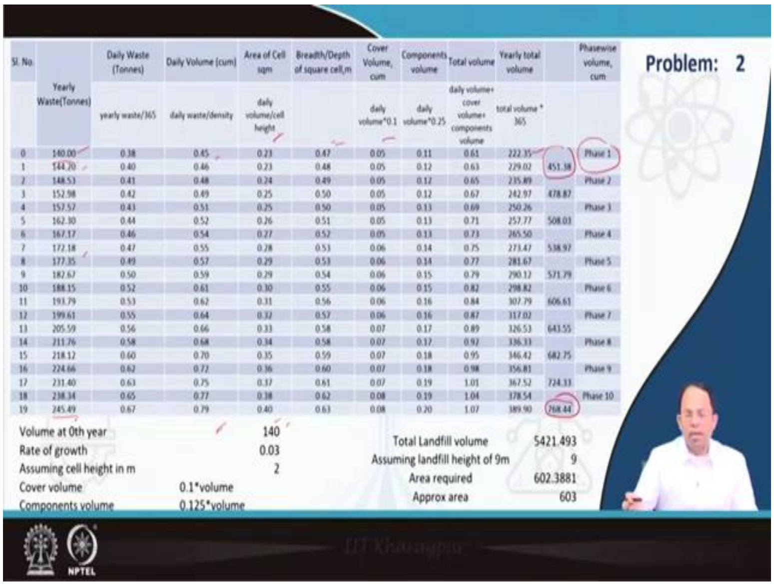

Sl. No	Yearly Waste(Tonnes)	Daily Waste (Tonnes)	Daily Volume (cum)	Area of Cell sqm	Breadth/Depth of square cell,m	Cover Volume, cum	Components volume	Total volume	Yearly total volume		Phasewise volume, cum
		yearly waste/365	daily waste/density	daily volume/cell height		daily volume*0.1	daily volume*0.25	daily volume+ cover volume+ components volume	total volume * 365		
0	140.00	0.38	0.45	0.23	0.47	0.05	0.11	0.61	222.35		Phase 1
1	144.20	0.40	0.46	0.23	0.48	0.05	0.12	0.63	229.02	451.38	
2	148.53	0.41	0.48	0.24	0.49	0.05	0.12	0.65	235.89		Phase 2
3	152.98	0.42	0.49	0.25	0.50	0.05	0.12	0.67	242.97	478.87	
4	157.57	0.43	0.51	0.25	0.50	0.05	0.13	0.69	250.26		Phase 3
5	162.30	0.44	0.52	0.26	0.51	0.05	0.13	0.71	257.77	508.03	
6	167.17	0.46	0.54	0.27	0.52	0.05	0.13	0.73	265.50		Phase 4
7	172.18	0.47	0.55	0.28	0.53	0.06	0.14	0.75	273.47	538.97	
8	177.35	0.49	0.57	0.29	0.53	0.06	0.14	0.77	281.67		Phase 5
9	182.67	0.50	0.59	0.29	0.54	0.06	0.15	0.79	290.12	571.79	
10	188.15	0.52	0.61	0.30	0.55	0.06	0.15	0.82	298.82		Phase 6
11	193.79	0.53	0.62	0.31	0.56	0.06	0.16	0.84	307.79	606.61	
12	199.61	0.55	0.64	0.32	0.57	0.06	0.16	0.87	317.02		Phase 7
13	205.59	0.56	0.66	0.33	0.58	0.07	0.17	0.89	326.53	643.55	
14	211.76	0.58	0.68	0.34	0.58	0.07	0.17	0.92	336.33		Phase 8
15	218.12	0.60	0.70	0.35	0.59	0.07	0.18	0.95	346.42	682.75	
16	224.66	0.62	0.72	0.36	0.60	0.07	0.18	0.98	356.81		Phase 9
17	231.40	0.63	0.75	0.37	0.61	0.07	0.19	1.01	367.52	724.33	
18	238.34	0.65	0.77	0.38	0.62	0.08	0.19	1.04	378.54		Phase 10
19	245.49	0.67	0.79	0.40	0.63	0.08	0.20	1.07	389.90	768.44	

Now, this is a little bit more detailed way of calculating, the exact same thing. So, instead over here what we have considered is instead of assuming the waste that is coming to the landfill site, for every year it is same, it is different, because waste is increasing every year. So, this is estimated over here as you can see in the 0th year waste is 140 tons, whereas in the final year waste is around 245 tons. So, obviously the total volume that is required to cover for this waste is also different in the different years.

If the total volume is different, then the area for each cell that is required would also be different, that is what it is given here. The breadth, depth and this for each Square cell that is would be also different the size of the cell, this is the area of the cell, this is the length size of the cell, covered volume would be different, components volume would be different liner and all, total volume that is required is addition of all this, and yearly volume that that it would be also different, so phase wipes volume we can determine because 2 years makes it 1 peso each phase would be of different volumes. So, that means that at the end of the day each phase will have different sizes. So, that also could be computed in this particular way.

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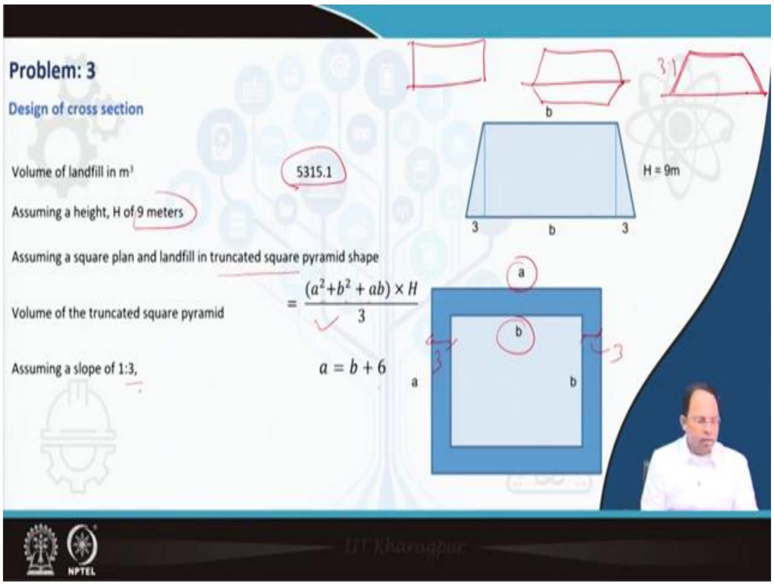

So, finally we come to the design of the cross section of the total landfill site, as we have discussed landfill is not a square, usually it starts at a base it could go both ways, it could be below as well as above. Let us assume that in this case this is a area fill method which is already mentioned. So, we started the ground we go up and we give a slope of 3 is to 1, something like that.

So, over in this case, we have this land the total volume is given this is the volume of the landfill site, this height is 9 meters, assuming a square plan and landfill is a is like a truncated square pyramid, volume of truncated square pyramid is this 1, a square plus b square plus ab into H divided by 3 where A and B are the sides squares, of course a truncated square pyramid is a square, the bottom base is has a length of a, the top base as a length of b, that is what the formula is and when we calculate it assuming a slope of 1 is to 3 a is equal to b plus 6, a is B and 3 this is 3 meters on both sides.

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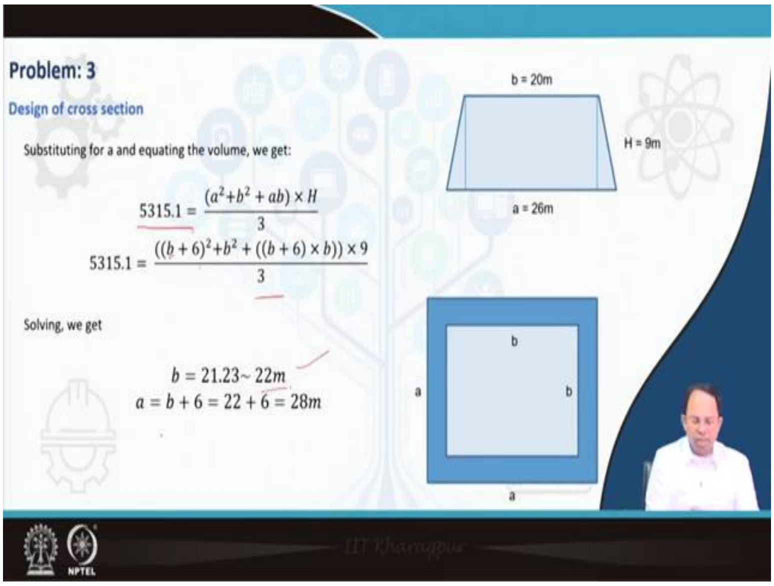

So, b plus 6 is a, and we can estimate it over here, we can say that b, we can put we can convert b, we can change b to if this replace each b with a with b plus 6, because a is b plus 6 because of the slope. So, in that case we can calculate the value of b which comes to around 22 meter and if B is 22 meters obviously a would be 28 meters. So, that gives us an idea about the shape profile of this particular landfill site.

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Finally, coming to the digit calculation problem. So, average total precipitation is given, only one phase is operative per year, we have to understand how much liquid is generated per year because the rest of the time there is cover given and after cover there is very little amount of infiltration that happens. So, that can be ignored or that would be become the part of surface water management. Then plan area for operating phase is different in each phase but we can assume it is the same one and we can say that based on the active area that is being operated upon the idea which is filled within intermediate cover the precipitation's volume should be different as per this rule.

But to make it simple we will go you do the calculation based on what we learned earlier that is assuming 80 presentation in a 4 month period, we will consider the peak leachate quantity that is generated, we can estimate that by multiplying the total Euro precipitation which is 0.6, 600 mm, it will take 80 percent of that, and this is the size of each cell, each phase, the area required for each phase and we divide it by 30 days into 4 months, and we get this is the total cubic meter of water that or sorry, leachate, that would be needs to be stored per day, this is how we can estimate that.

So, we can do that by is by taking an average value of the active phase area that is being walked upon and we assume that the entire area around this, whatever infiltration is coming over here we are that is being considered what is false over here, and then we can do this particular estimate, because it is a active area most of the water populates inside. So, based on that we can do this calculation but anyway. So, this is a much-complicated calculation which could be done following water balance analysis and the health model that we have discussed earlier, but crudely we can do this kind of estimate.

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Now, coming to two case studies, we will first discuss about this landfill by the Ahmedabad Urban Development Authority at Fatehwadi in Ahmedabad. It is a shared facility of 12 Nagar Palikas of waste Ahmedabad Urban Development Authority, it serves 10 lakh people every day, around 200 tons of waste comes to this landfill site. The annual rainfall of the site is 300-millimeter, groundwater table depth is 6 meters, and the soil is sandy.

Now, what design has been done? As you can see this image of this particular landfill site and Total Disposal capacity is determined as 1 around 50 considering 50 tons per day for eight-year period. around 1 lakh 45 thousand 534 cubic meter. this is the total disposal capacity. Landfill size design is 151 meters into 122 meter and the height is 7.9 meters. amended clay liner of 900-millimetre thickness with 10 percent bentonite clay, HDPE liner 1.5-millimetre-thick which is standard, 300 millimetre thick protective soil cover over HDPE, drainage layer is 300 millimetre thick with 100 millimetre protective soil cover, digit collection and treatment facility is 1 via 150 millimetre die pipes.

Earlier we have learned 200-millimeter diapers but here they have adopted 150 millimetre pipes HDPE perforated pipes are used legit collection tank is given which is 2 meter by 2 meter into 3 meter, which is the height. Gas liquidant is transported by tanker and discharged to a nearby trunk sweat. So, that means through the sewerage network the leachate is transported to a switch treatment where it is gets treated with the normal switch. Gas collection system is by HDPE event type of 200-230 mm diameter and also storm water drainage is also constructed. So, this is how the landfill design has been done, scientifically design has been done by the Ahmedabad Urban Development Authority.

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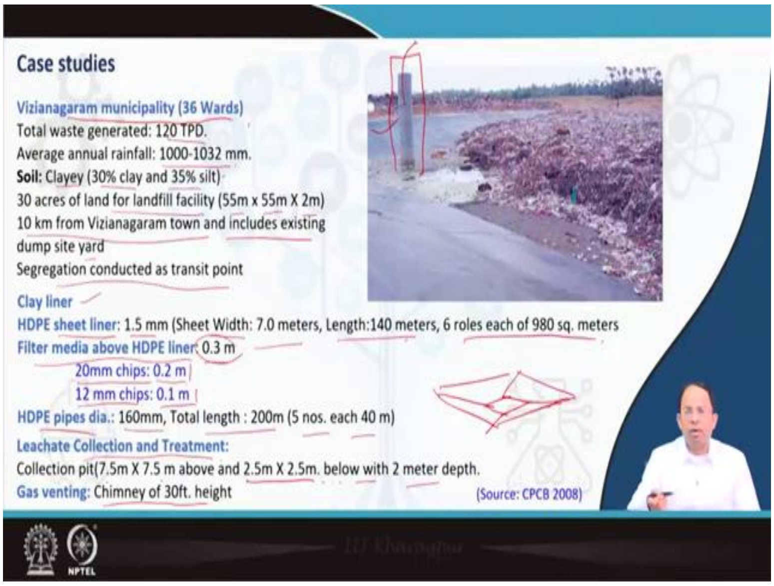

Next, coming to another landfill design in Vizianagaram municipality which has got 36 Watts, you can see this pipe sticking out, this is the gas collection well a passive Bell. So, this allows the gas to come out of the lower layers of waste which is below here. So, total waste generated is 120 tons per day, average annual rainfall is 1000 to 32 millimetre, clay soil is available, 30 percent clay and 35 percent silt. So, because of that there is no need for separate, your amended soil and all these things required which was required in the earlier case.

30 acres of land per landfill facility with 55-meter, 55 meter and 2 meter 0 depth. So, 10 kilometer from Vijayanagaram town and includes existing dump site yet. So, already the existing yard is also there at the same location segregation conducted at Transit point. So, segregation of waste is conducted at Transit point.

So, a clay liner is utilized using the same soil that is available inside, HDPE sheet is additionally added which is a 1.5-millimeter thickness. now the sheet with. each sheet is 7 meters 0 in width length is 140 meters and that means each six rolls of 980 square meters. each is required to cover this particular site.

Filter media above HDPE line at 0.3 meter, which is standard, the drainage layer is of 3.3 meter, which includes 20 millimetre chips and 12 millimetre chips 1 is for 0.2 mm and other is for 1 mm height, so for 1 feet and 2 feet. HDPE pipes 160 mm total length 200 meters five numbers of pipe each 40 meters apart has been designed. Digit collection and treatment is via through a collection pit 7.5 meter into 75 meter above M larger above and 2.5-meter, 2.5 meter below with 2 meters depth. So, that is the design.

Gas venting is via a chimney of 30 feet height, that is this gas venting. So, this is how landfills have been designed in India. So, these are some examples of them and similarly all landfills in future needs to have as we have discussed in the gas management system active one's, leachate Management Systems, Water Management Systems, surface groundwater systems, so on.

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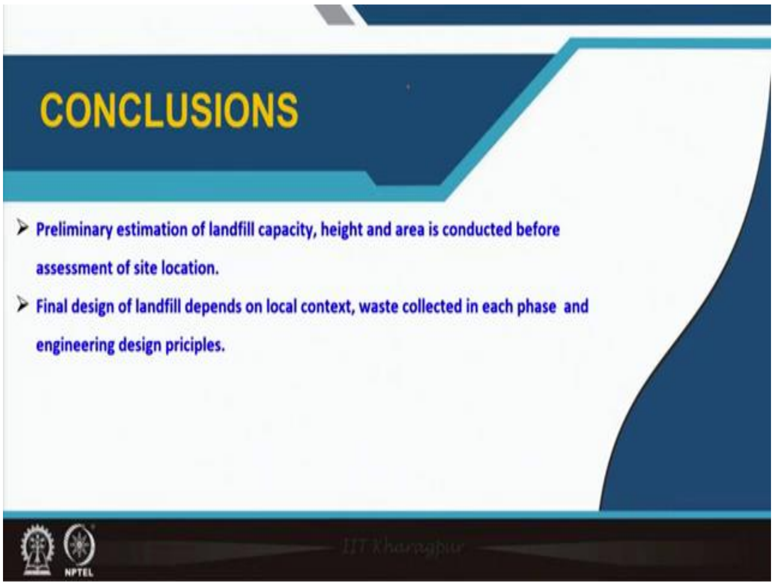

So, these are some of the references you can study. So, to conclude preliminary investing estimation of landfill capacity height and area is conducted before assessment of site location and final design of landfill depends on local context, waste collected in each phase, and engineering design principles. Thank you.