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

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Lecture - 37
Stability of Incrementally Raised Embankments - Part 2

Good day to all of you, and today we will continue our discussion on stability of incrementally raised embankments this is what we started last time. And we will carry it through to see how we make these embankments stable, what are the critical factors which effects stability; and what are the design issues that we should be looking at very carefully while raising these embankments incrementally.

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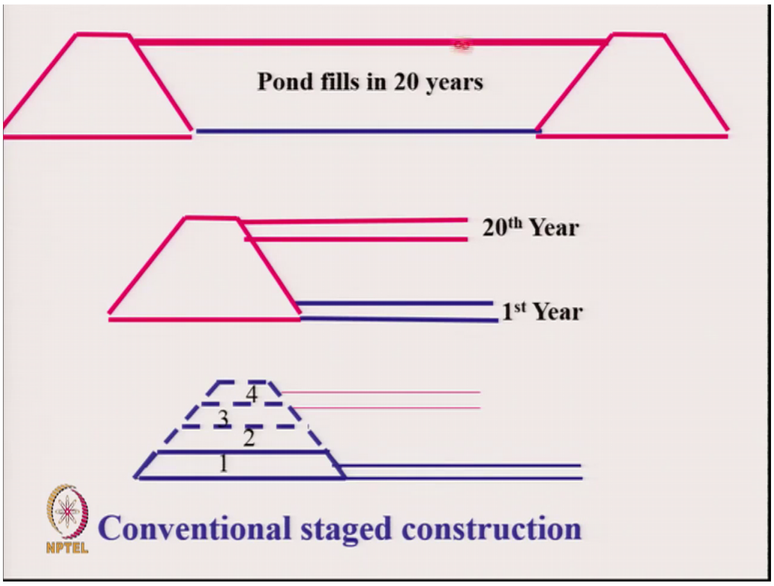

So, last time if you recall we had said that a pond may be filled up in 20 years and we would like to raise it incrementally if I use the traditional method. Suppose, I wants to raise it once every 5 years then it would come to the top in 20 years. So, this would fill up in 5 years then this would fill up then this would fill up hen this would fill up, this is the conventional way of making a dam. So, making an embankments incrementally by the conventional method is not very suitable because in the beginning you have to make a very wide base and then as you go upwards, you have the width decreases as you go upwards, but a lot of investment in earthwork takes place in stage one.

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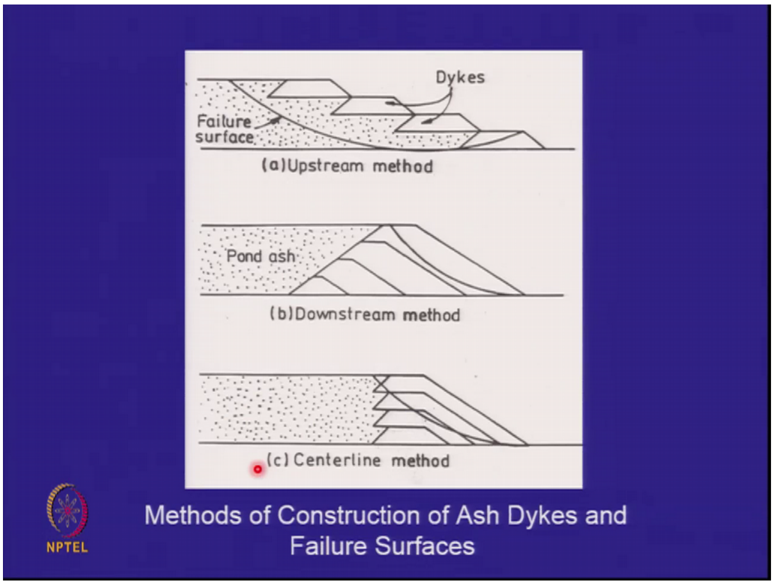

So, conventionally what we do is either you use upstream method, where the earth work is smaller as you can see or the downstream method where the starting earth work is small and as the dam progresses more and more earth is added as you go upwards. And the center line method is in between the two the difference in stability is the typically the failure surface in the upstream method passes through the loosely deposited slurry material. And the factor of safety of this slope is usually low during earthquakes. In the downstream method, the critical failure surface passes through the compacted material. So, the stability of the embankment is better. In the centerline method, it is a hybrid of the two.

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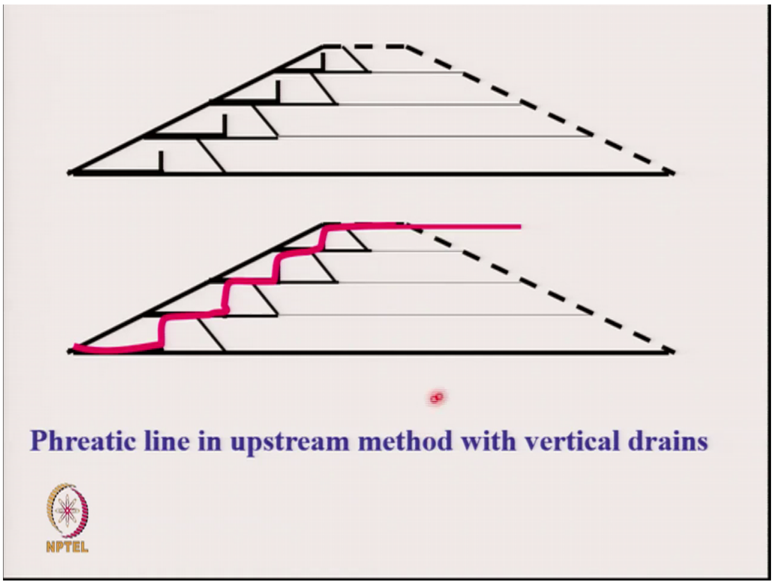

One thing which I talked about in the upstream method as we can see the internal drains are provided in each dyke; and consequently the phreatic line which develops is close to the downstream slope.

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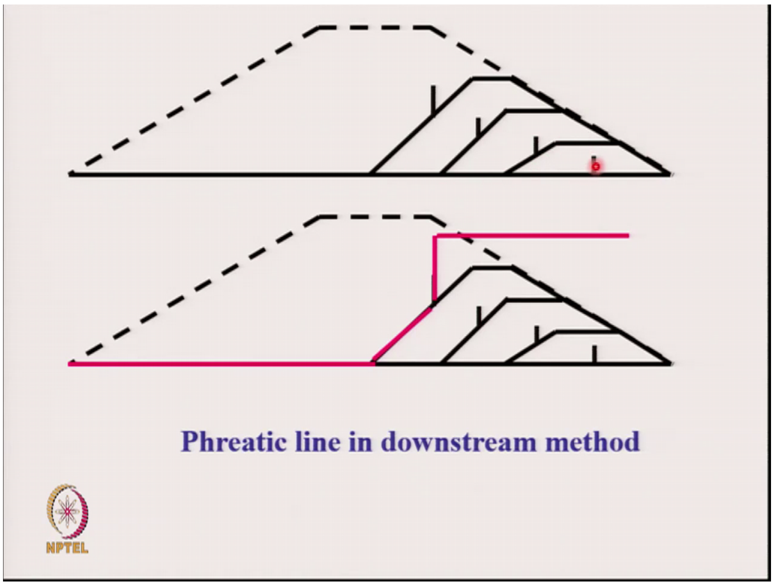

In contrast, in the downstream method of construction the drains are far away from the downstream slope, this is the final drain. Consequently, a phreatic line looks like this, bulk of the embankments is not saturated.

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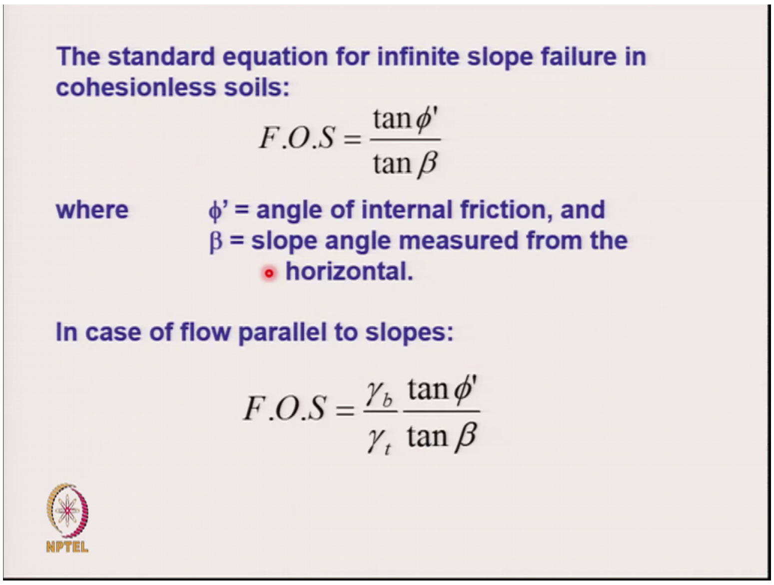

So, we looked at the fact that the factor of safety could be evaluated using the infinite slope failure methodology for the dry case and for the flow parallel to the slope case. And we said that the factor of safety when c dash is 0, becomes tan phi dash by tan beta and if there is flow parallel to the slope it becomes gamma b by gamma t tan phi dash by tan beta.

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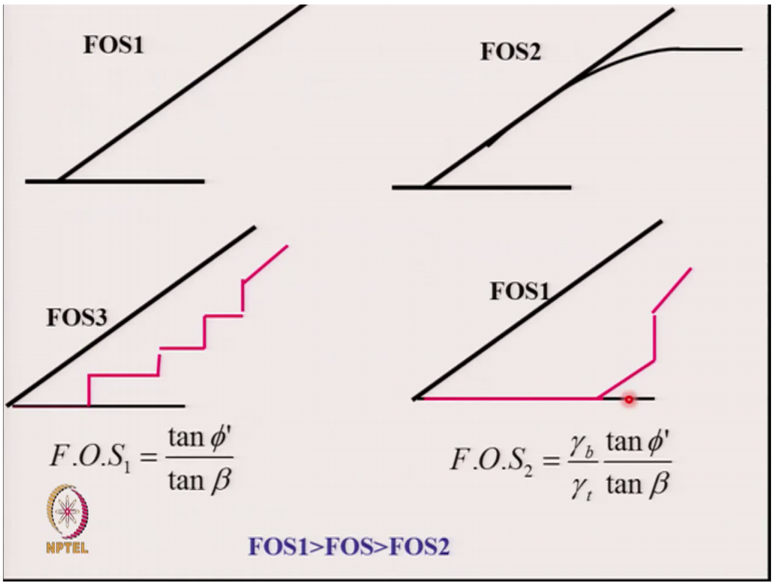

If I look at the phreatic line in the case of dry soil, there is no phreatic line. So, the factor of safety is governed by tan phi dash by tan beta. If there is upstream reservoir is full and for some reason there is no internal drain, then the phreatic line will come and join the downstream slope. So, flow here is parallel to the outer slope, so the factor of safety in this case becomes gamma phi by t gamma phi by gamma t tan phi dash tan beta by tan beta. So, this has a high factor of safety and this has low factor of safety.

If I look at the upstream method of construction, my phreatic lines look something like this. Here the flow is close to the surface in the downstream method of construction the phreatic line looks like this it is far away. So, the factor of safety for the downstream method of construction is very similar to the factor of safety for the dry slope, because this is primarily dry and your failure surface will probably go like that. Whereas in the upstream method, the failure surface goes a little deeper and therefore, the factor of safety lies between these two values, this is high, this is low and upstream method lies somewhere in between.

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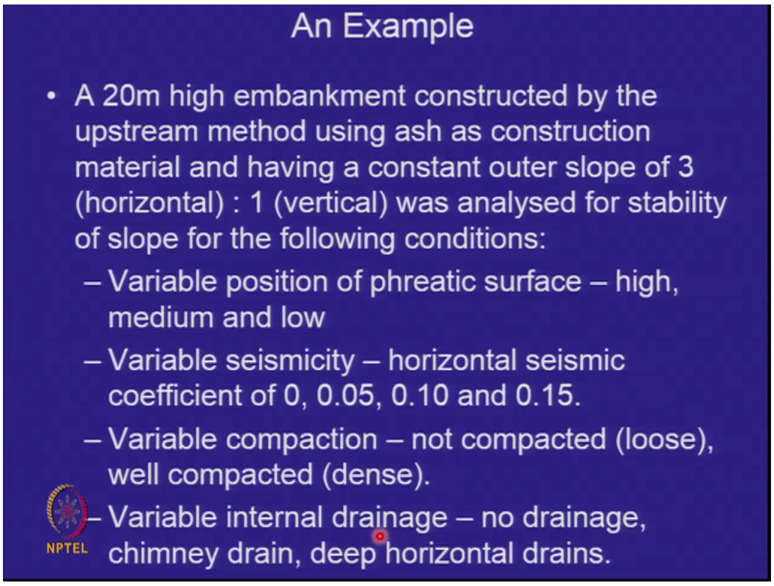

So, I am going to take an example and show you how various parameters effects the stability of embankments constructed by the upstream method. A 20 meter high embankment has been constructed, the outer slope has been kept three horizontal to one vertical. And we have varied the phreatic line, we have varied the horizontal seismic coefficient, and we have varied the compaction as well as the internal drainage, so that is the problem that has been analyzed.

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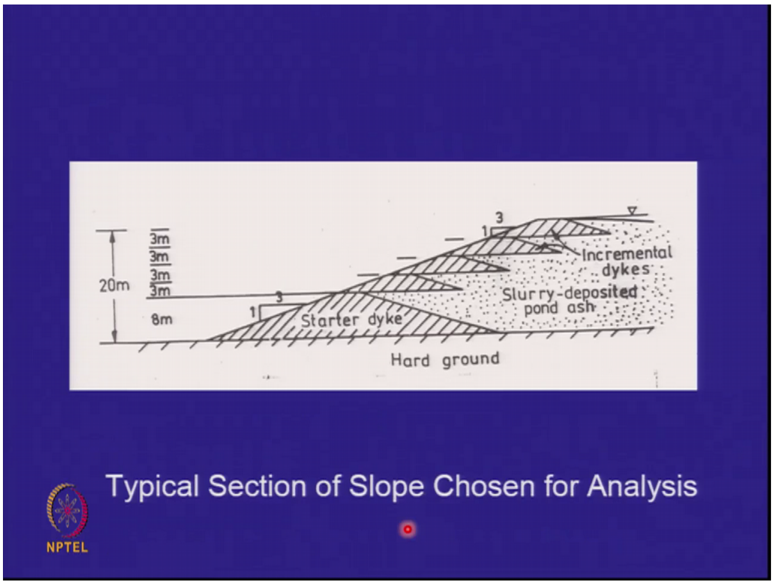

Please note that his is first starter dyke is 8 meters high, and here are 1, 2, 3, 4 reasons of 3 meters, the downstream slope is 3 is tau 1. And there is no offset at the level of the crest. Normally, you may have this kind of a construction or many times you move the upstream dyke a little behind and leave a 2 to 3 meter wide pathway, so that that can become an inspection path.

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- The material properties of the ash used in the analysis are listed in Table 1(Datta et. al. (1996), Sridharan et. Al. (1996)).

Table 1: Ash Properties Used In Analysis

Type	G_s	γ_d (gm/cc)	γ_{sat} (gm/cc)	c (kg/cm^2)	ϕ (deg)
Uncompacted, loose pond ash	2.0	1.10	1.55	0	28
Compacted, dense pond ash	2.0	1.40	1.70	0	35

Way we used this analysis for an ash pond. So, the properties of the ash for loose uncompacted ash, this is hydraulically deposited and compacted ash which is compacted by rollers were taken. The important thing to notice is that the phi dash for the hydraulically deposited ash was taken as 28 and for the compacted ash was taken as 35.

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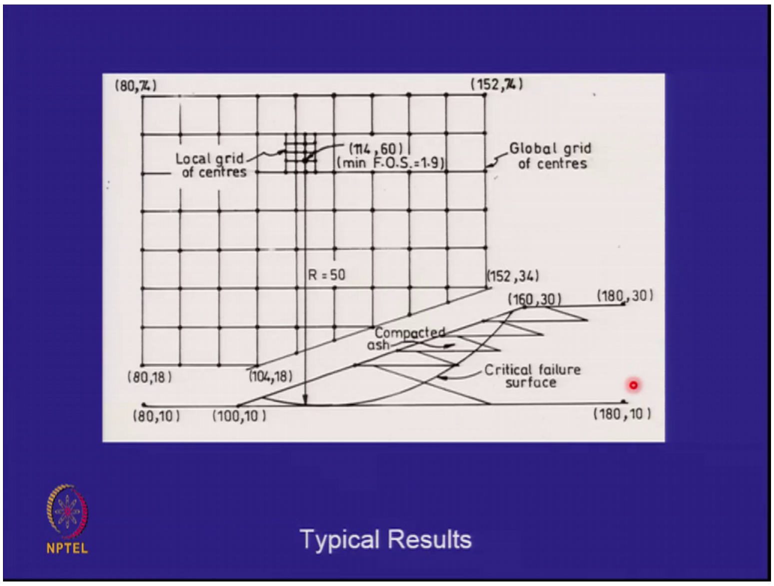

And stability analysis were done using (Refer Time: 06:35) methods using a grid of centers and the minimum factor of safety was identified for the critical failure surface.

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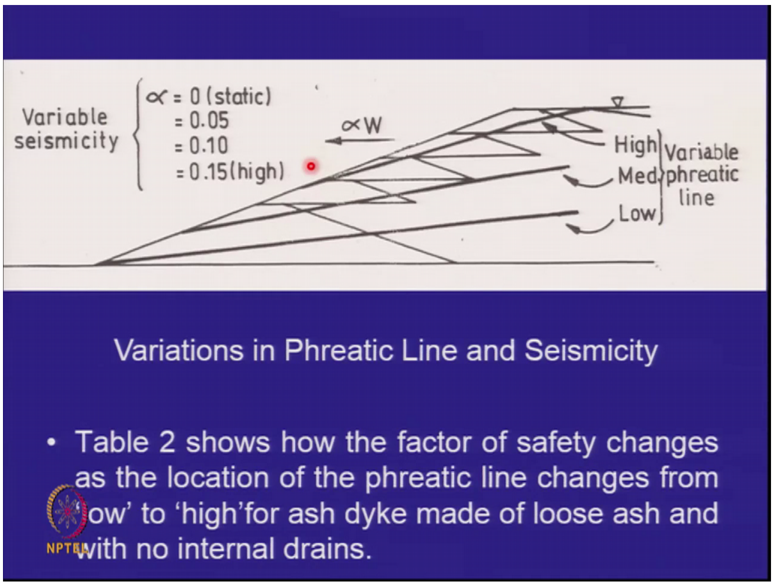

So, here is the first set of variables. What is stated is you could have a high phreatic line, a medium level phreatic line and a low phreatic line. When will the phreatic line will be low when the pond is of low height ashes just filled up a meter or 2, and the water is one or two meters in the pond. As the dykes raise and as the ash raises water levels will go up. So, here what it shows is that towards the end of the life, your water level will be very close to the top and then you may develop a high phreatic line. So, intuitively what we can say is for low phreatic line you will have a higher factor of safety; and for higher phreatic line you will have a low factor of safety. And also we have said that let there be no seismicity to 0.15 alpha h. So, this gives you the kind of seismicity.

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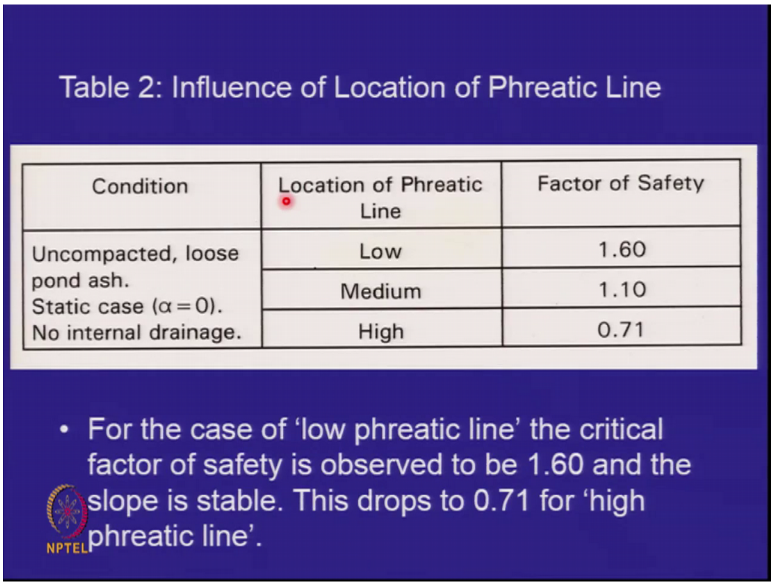
Table 2: Influence of Location of Phreatic Line

Condition	Location of Phreatic Line	Factor of Safety
Uncompacted, loose pond ash. Static case ($\alpha = 0$). No internal drainage.	Low	1.60
	Medium	1.10
	High	0.71

- For the case of 'low phreatic line' the critical factor of safety is observed to be 1.60 and the slope is stable. This drops to 0.71 for 'high phreatic line'.

So, how does the factor of safety change. If the embankment is on uncompacted loose pond ash, alpha is 0 there is no internal drainage when the phreatic line is low we get a factor of safety 1.6, but when the phreatic line is high we get a factor of safety of 0.71. So, when the phreatic line is here the factor of safety of this slope is 0.71; when it is here it is 1.6. So, if you recall the acceptable factor of safety is 1.5. So, this looks good. So, this embankment or these incrementally raised embankments will remain stable as long as the phreatic line is low, but the moment phreatic line becomes high, the factor of safety will fall below one and you will have a failure.

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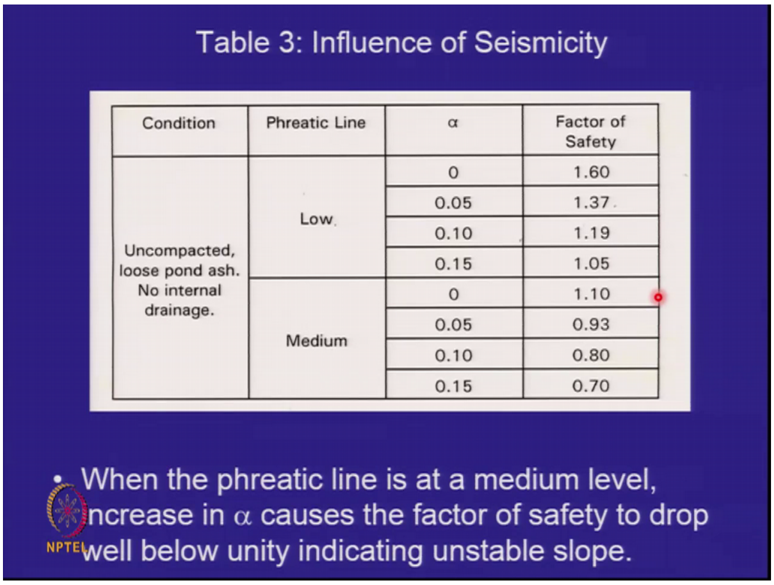

Condition	Phreatic Line	α	Factor of Safety
Uncompacted, loose pond ash. No internal drainage.	Low	0	1.60
		0.05	1.37
		0.10	1.19
		0.15	1.05
	Medium	0	1.10
		0.05	0.93
		0.10	0.80
		0.15	0.70

If I now add onto it seismicity, now do remember that the acceptable factor of safety for a static case is 1.5 and the acceptable factor of safety under earthquakes is 1.05 or above. So, I remember that for low phreatic line no earthquake I had 1.6. And as I increase my alpha values, the factor of safety falls; at 0.15 which is pretty high you get a factor of safety of 1.05. The slope still remains stable because 1.05 is the acceptable factor of safety for a small duration event. However, in the medium phreatic line case, where the factor of safety was above 1.1, during earthquake it falls to 0.7 indicating a gain that if you have a medium level of the phreatic line and a earthquake comes which is above 0.5 g in the horizontal acceleration your embankment is likely to fail.

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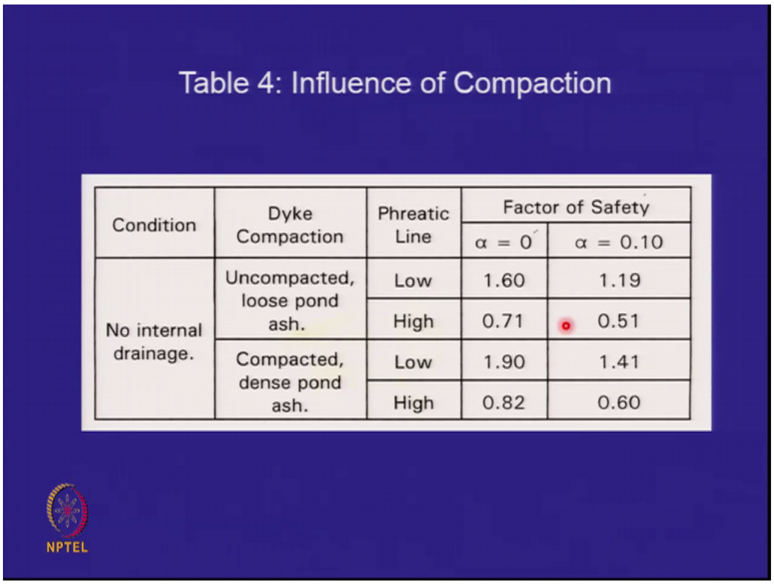

Table 4: Influence of Compaction

Condition	Dyke Compaction	Phreatic Line	Factor of Safety	
			α = 0	α = 0.10
No internal drainage.	Uncompacted, loose pond ash.	Low	1.60	1.19
		High	0.71	0.51
	Compacted, dense pond ash.	Low	1.90	1.41
		High	0.82	0.60

Does compaction make any difference well lets up the phi value from 28 to 35 let say we are able to compact the entire ash by some means then what happens when the phreatic line is low I had 1.6 if you recall. If I compact the ash the factor of safety goes to 1.9; as long as it is low 1.6 falls to 1.19 under an earthquake, but do remember uncompacted loose ash when the phreatic line is high anyways this embankment was failing.

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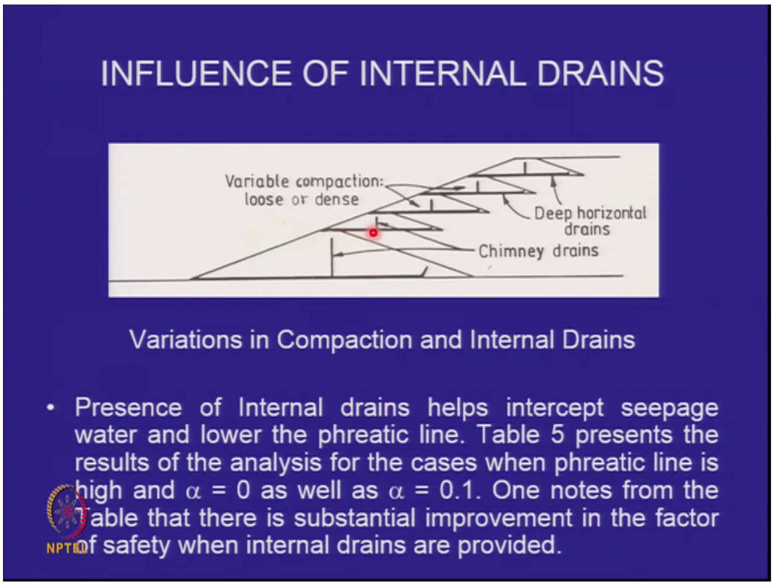

Can compaction prevent this failure, that is the question we are like to address 1.6 went to 1.9 when the ash is compacted that is very good, but 0.71 went only up to 0.82.

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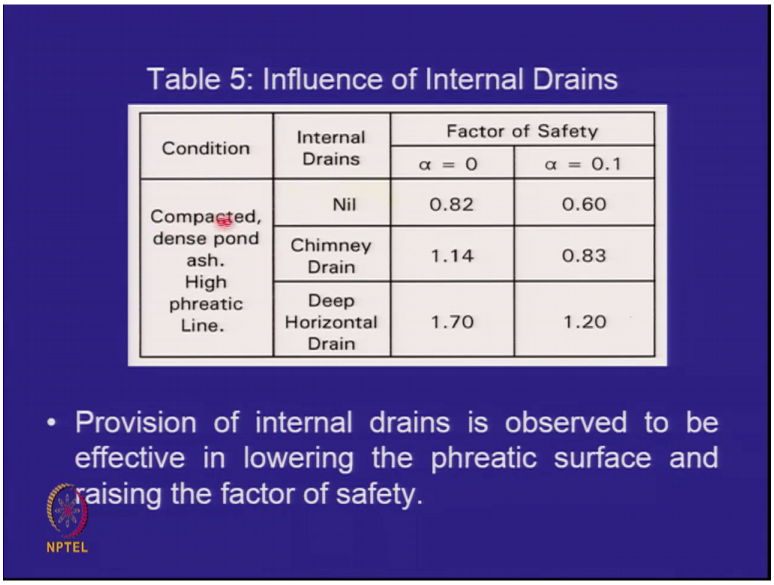

Condition	Internal Drains	Factor of Safety	
		$\alpha = 0$	$\alpha = 0.1$
Compacted, dense pond ash. High phreatic Line.	Nil	0.82	0.60
	Chimney Drain	1.14	0.83
	Deep Horizontal Drain	1.70	1.20

So, compaction cannot offset, the problem of a high phreatic line if there are no internal drains because the phreatic line starts meeting the downstream slope, and your factor of safety tends to become gamma b by gamma t tan phi dash by tan beta. Now, what we do is we install internal drains, the two options I can install a internal drain like this a chimney drain at the midpoint of the base. And another option is that I can take the drain even back deeper. The idea is that when the internal drain is in the form of a chimney drain hen your phreatic line will be joining the top of the chimneys whereas, here it will be back. So, the phreatic line will become a little more further away from the downstream slope. However, there is a danger if you take this very deep, and there is water here the seepage levels will be higher, you will get more water out of the pond because it is very close to the upstream slope.

So, what do these drains do. Let us have a look. We remembered that when we had compacted dense pond ash, we had gone up from 0.71 to 0.82. Now, I put a chimney drain I get 1.14 that is the substantive increase. And if I put a deep horizontal drain high phreatic line I get 1.70. So, the drain is the most critical requirement if you can put a good drainage system, you will get a stable embankment.

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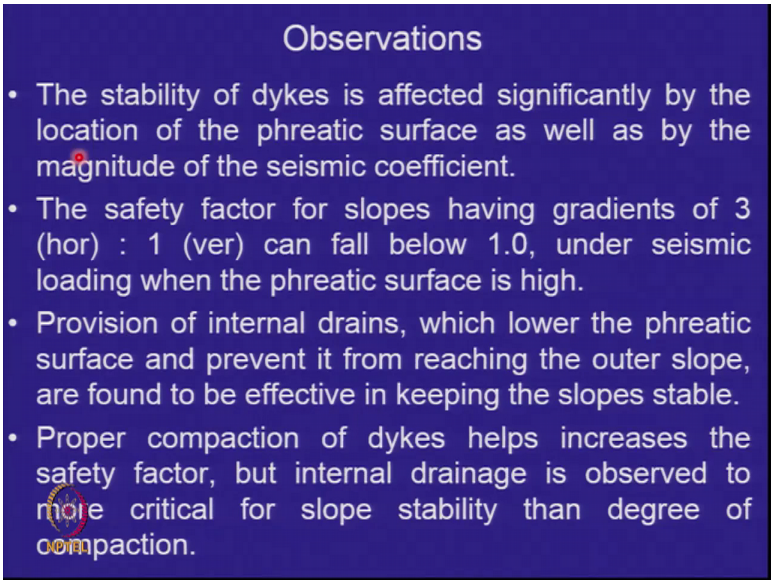

So, observations the stability is of the dykes is significantly affected by the location of the phreatic line as well as the magnitude of the seismic coefficient. And we were looking at a slope of three is to one. And three is to one if there is no drain you can be a failure. Three is to one you have deep drains you may not have failure because the phreatic line is kept well away from the surface. So, proper compaction helps increase the factor of safety, but internal drainage is the most critical factor for slope stability, so that is the message that I am trying to get you keep the phreatic line well away from the downstream surface.

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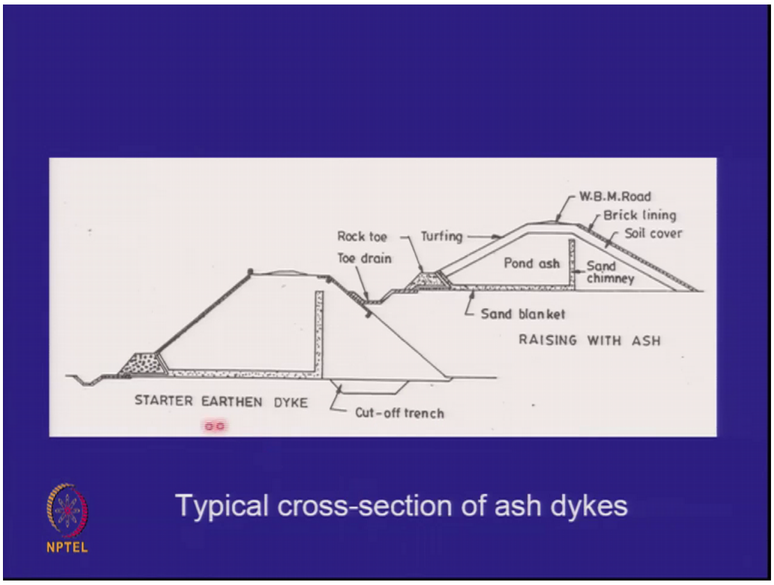

So, if you look at the ash ponds designed by NTP see National Thermal Power Corporation, you will find the designs like this. Typically this is three is to one slope, but they keep their embankments away from the crest. So, though this is three is to one and this is three is to one, the total slope is about 3.5 is to one the average slope because every time the embankment is kept away it is not continuously going up. Secondly, they keep the chimney drain and blanket drain and a rock toe. So, in this manner, they are able to keep the phreatic line away from the downstream, and there collecting the water of each stage in a toe drain and taking it away.

So, we are not allowing the water of this drain to come here, but if it overflows it will come here this water is collected in this drain and the lateral direction the water is taken out by over flow. So, that is the design which is used for upstream raising. Do remember that in any case this ash is not been compacted. So, you still have some times issues about this being very well made but the failure surface going through soft ash or loose ash and giving you failure.

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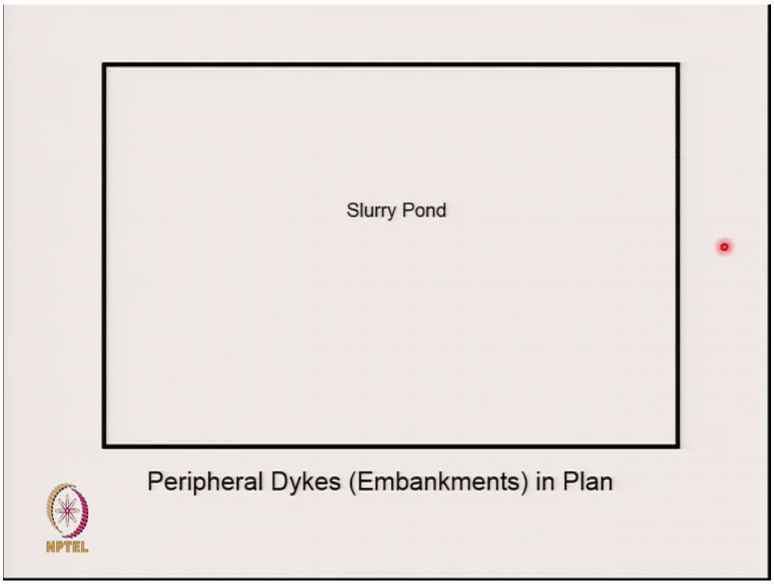

Critical to all this is the location of the decantation well and let me try and highlight this problem. This is the slurry pond. Let us say this is the area that is been given to us for the purpose of design of a slurry pond. And we are going to do upstream method of construction. So, I need to have two ponds. So, what I will do is I will bifurcate this into two so that one pond can be working another pond can be closed.

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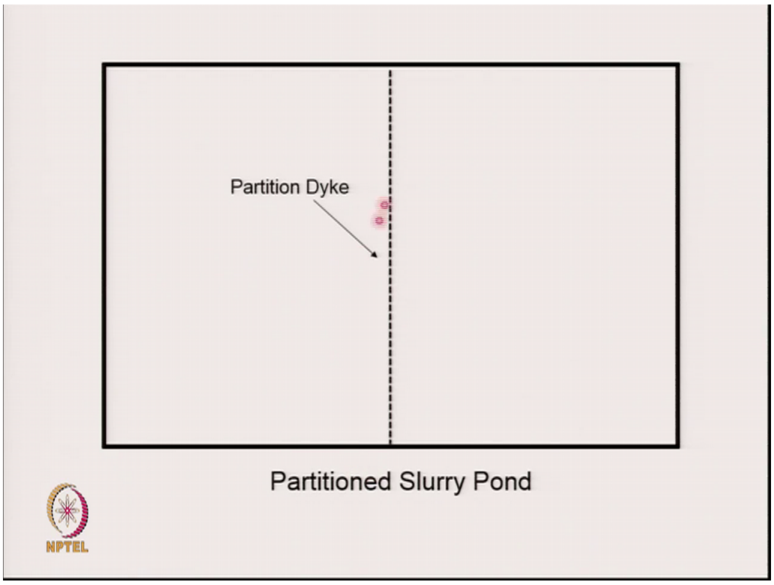

So, I do the partition I do a partition dyke, now I have two ponds. One can be working at one time, the other can be closed the other can be working at one time the first one can be closed and I tend to keep the decantation wells close to the embankment.

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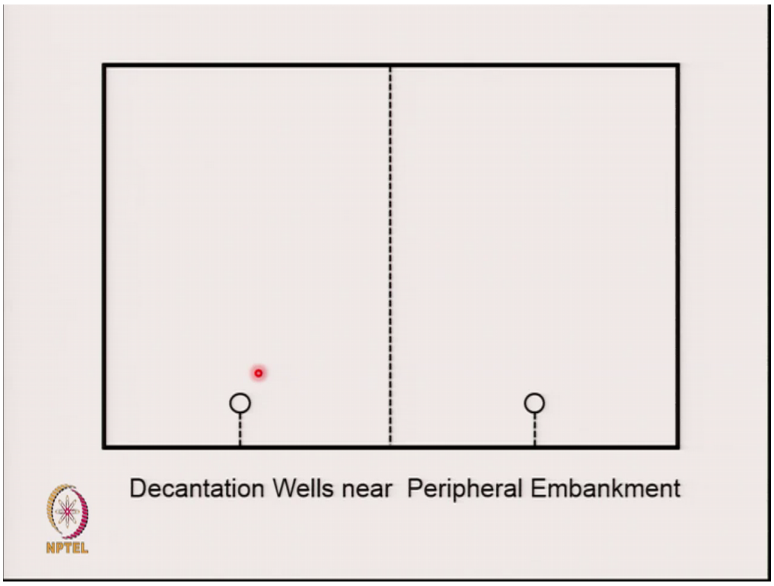

Why, so that I can reach them for maintenance you I recall I have shown you the location of the decantation well is typically closed to the embankment. If you are closed you can put a little connector from here to here and you can maintain it, you have to go and close the openings the ports from time to time as the water level raises. So, you have the decantation wells there. In such a situation where will you put your slurry in flow points we have talked about garlent canal. So, I will put my slurry in flow points here far away from the decantation well, so that the if I put a inflow point here the slurry has to travel this much distance and the fines will settle down; if I put it very close, it will be an issue.

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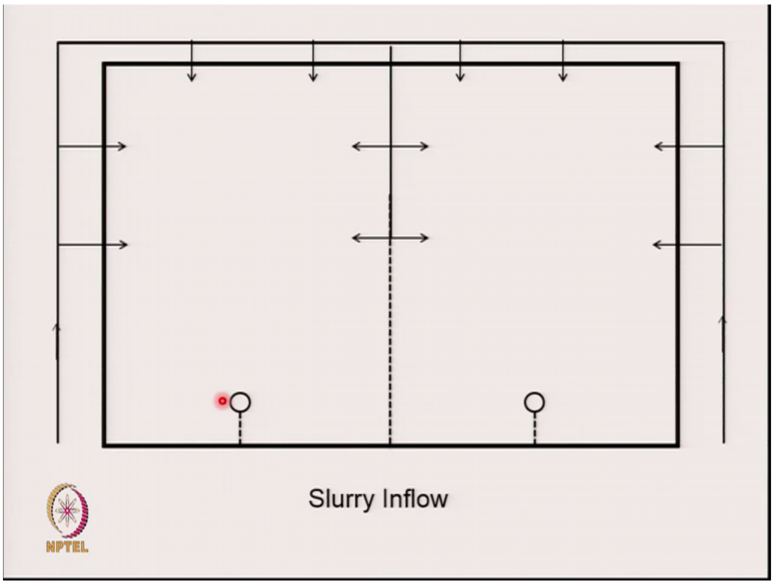

So, this is the way by which you do a garlent slurry arrangement, your slurry pipeline comes here. And let us look at this pond you will be sending in the slurry from time to time through these inflow points. This distance will still have to be the minimum distance required for the purpose of settling of the fines. Now, when I allow inflow like this where will the coarse particles settle and where will the fine particle settle, the coarse particles settle close to the inflow point, this will have a decantation pond in the sense the water will. So, the fine particle will tend to settle here.

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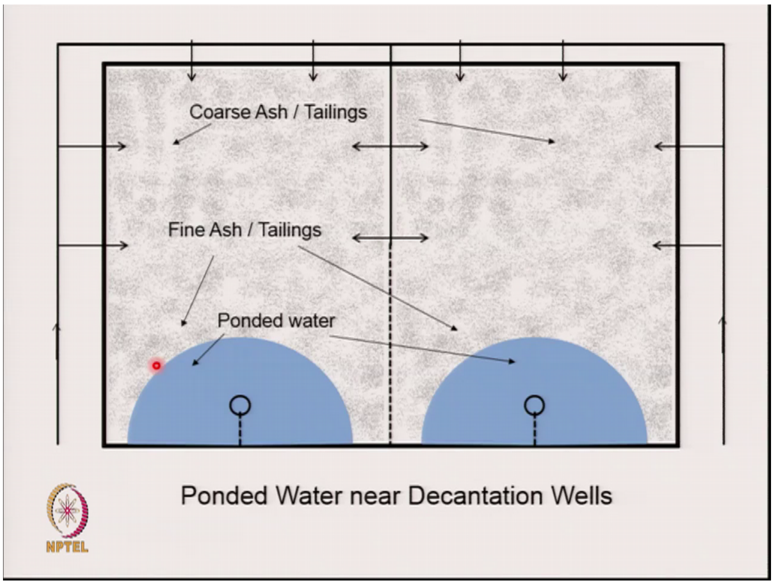

So, let us look at this I will have coarse action tailings very close to all these area, but I will have fine ash and tailings here. So, what happens I have to raise this now by the upstream method. The upstream method means my new dyke will come on the inside of the pond right here, here and here. So, I can stop one of the ponds and allow this to dry up and I can make my pond like that. The only problem is that on this end I am having fine tailings.

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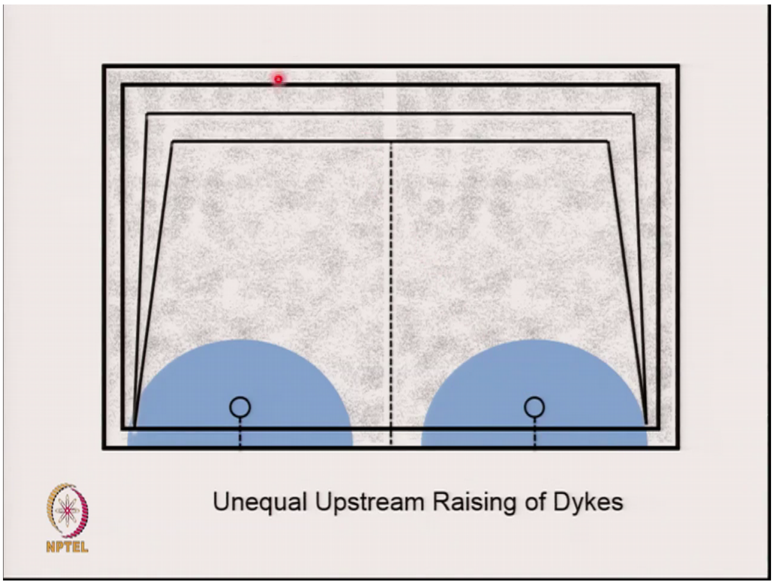

So, the strength is low, they do not dry out that easily because they hole more water and many a places you will find that the increase of height of the dam of the pond is like this. You are able to increase height here by moving the dyke inwards after three years and again after three years and again after three years. On this side you have increased it after three years, but now you find that your decant value is getting buried is if you start moving inwards then you should have kept your decant well away well away taking into account the fact that you will have five raisings. If I wanted five raising, may be the well should have come here. So, normally if this is the problem which is encountered in many of the old slurry ponds that the decantation well has been kept very close to one of the main embankments and this creates a problem.

How would you tackle this problem, I would like to keep the well here. If I keep the well here the only problem is how to reach it, I will have to reach it to maintain it. So, anyways what currently is done as you will see is that after one raising or two raisings, when you come very close to the decantation well you move the well on the upstream side. So, first your first dyke is here after four or five years if it fills up the second dyke is here, after four or five years if this is getting buried you put a cross connector and make another well here and then you do the raising. Still you are doing the raising on fine ash, which is not something which you cannot do because you can make the slope very flat, but not desirable, you should have coarse ash or coarse tailings on which you should put your embankments. So, is there another way of doing this, which we not adopting yet, well one would like to propose the following.

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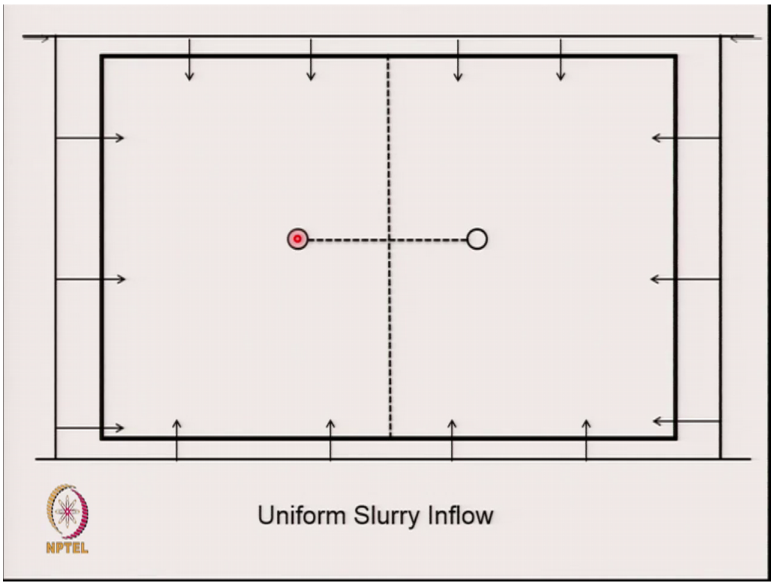

Let us say we have the same slurry pond. And I make the partition. Now, another way of doing this is to put the decantation wells here. Please see the location of the decantation well. Now, what is the how are you going to reach it we anyways have a partition embankment.

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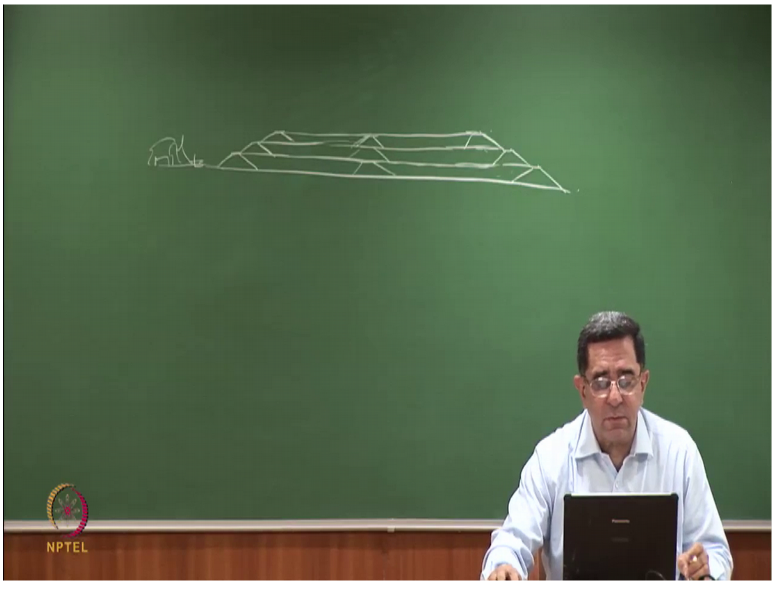

Now, what is the partition embankment, it is not a permanent embankment. Please note that the pouter embankments are the permanent embankments which are going to be there for the whole life of the pond and even afterwards if I was to trying capture this. This is my starter dyke. Let us say I am going to have three raisings. So, I have my three raising, and this is the final. These external slopes are going to be there always. What is the partition dyke, partition dyke is that you make a dyke here in the center. You make a dyke. So, you can use this one at a time and this another at a time.

Now, you want to go higher what will you do. When this pond fills up, how will you make your next dyke, you can make it by the center line method right you can make it by the center line method and like this we can go up. Now, what is different between the sorry between the other dykes and this dyke, these dykes are not permanent dykes, why they will become buried with time. Suppose, this is end of your twenty years of operation of the ash pond the dykes are buried. So, even you one dyke fails, slurry goes from one pond to the other; whereas, these dykes cannot fail because there will be village or humans or road something nearby. So, you cannot send your failed slurry into habitation or into a infrastructure facility.

So, partition dykes are temporary. So, what happens is I make my well close to the partition dyke and that is what I have shown here. You can always drive on this, and you can drive on this and then you can have a connector. So, now what happens how does the raising takes place. Now, when I have the decantation wells more towards the center, what is happening your garland can all garland pipeline arrangement can be like this. Now, when you can have like this, then the coarse ash will fall here, coarse ash will fall here. So, this is an alternative way of doing things. Yes, the decant pipes will be longer, you are going to have a decantation pipe coming through this will be longer, no doubt about it; however, this is reachable from here, and this is reachable from here.

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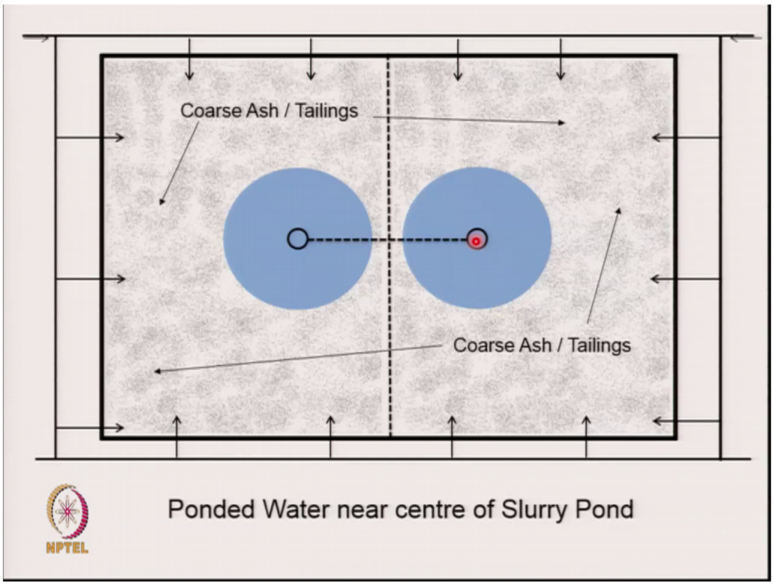

Then how does it play out, the coarse ash settles here all along and the decant pond zone the water comes here, the fines are here. So, the fines are in this portion, agreed. Now, if I want to do my incremental raising, I can actually reduce it like this because this is coarse ash all along. The partition dyke will go up by the center line method. So, it will not bury the two decant well with time; the partition dyke is setting on fine tailings or fine ash ok, its stability is little less. However, the partition dyke is only going to be visible for 3 to 4 years then it will becomes buried. So, it is not going to be something which is going to have a catastrophic effect in terms of failure.

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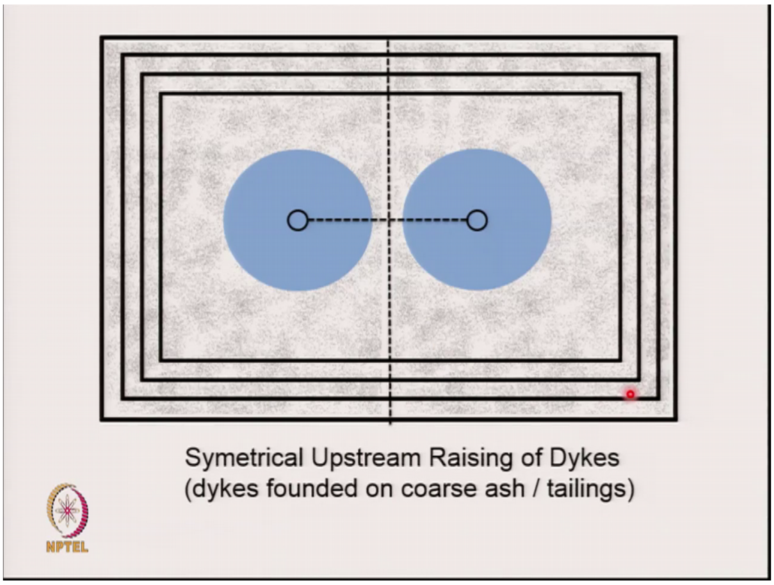

So, then what you find is that the raisings go like this. Now, you are able to raise the everything on the inward side you know symmetrical manner and your ash pond or a tailings pond which is like this becomes keeps on coming closer. And say you have reached your height of 15-20 meters you can close it at the top even you can go higher and close them, but you are putting your embankments on your coarse material and that is the way it looks.

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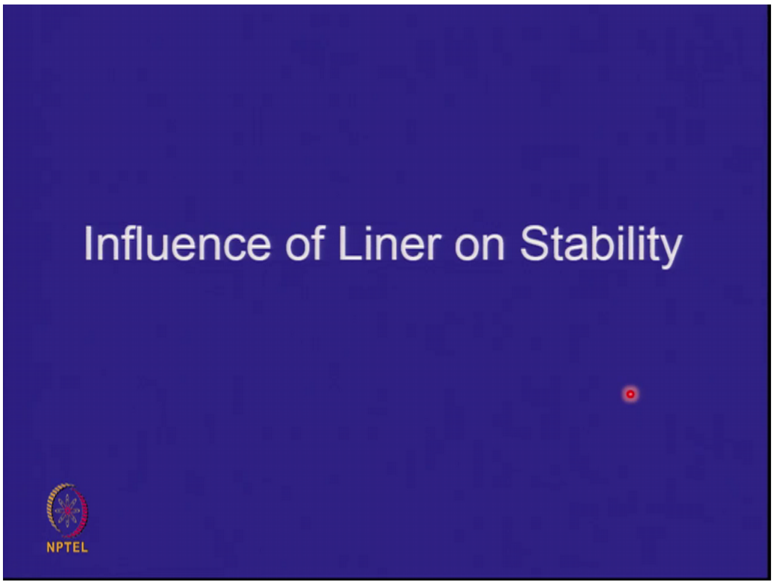

This one more aspect out stability which I would like to talk about now phreatic line is very important and remember in all that we showed you here where is the water now, the water is far away from these embankments. Can I just show go back to the earlier thing, where is the water here, the water is here right. As far as the stability on this side is concerned it is not a problem because the water level is far away, but what about these embankments, the water is impounding on them that means, the phreatic line on this side is always going to be high, it is always going to be high. Whereas, now in the new arrangement, the water level is far away.

Of course, it is still possible that you have excess and you are filling this up like a lake that is possible, but bulk of the time the water could be far away. Therefore, the phreatic line as far as the outer embankments are concerned would be low and therefore, the stability of the outer embankment should be better. So, all the new arrangement also allows you better control over the phreatic line. But one more thing is happening and that is the requirement of liners. Over the past 2-3 years more and more regulations are coming in that you must have liners at the base of all slurry ponds and this is having an effect because the moment you put a liner the water cannot go down. And therefore, it tends to remain inside the pond and that has an effect on the phreatic line and let us have a look.

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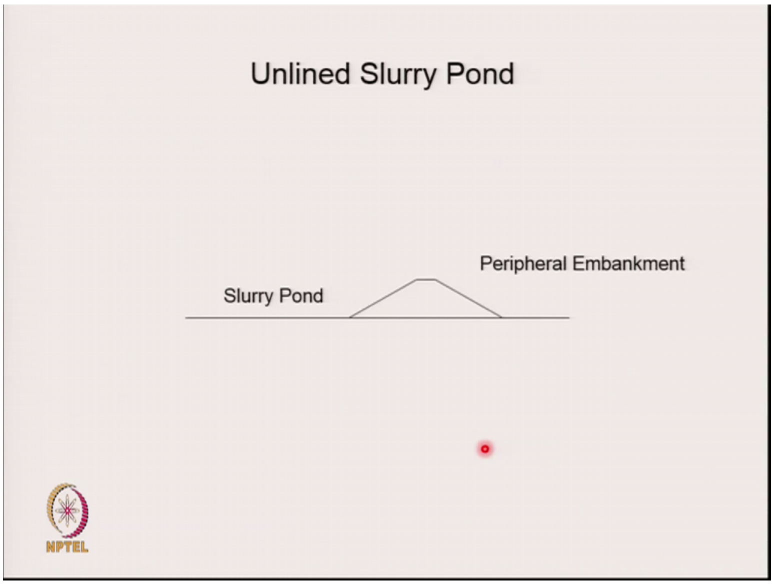

So, let us say this is my slurry pond this is the peripheral embankment earlier it was unlined right. And what use to happen you would have your ash and slurry water up to this point and then I had to make the next raising. So, I would stop one portion of my pond from working and do my discharge in the other portion.

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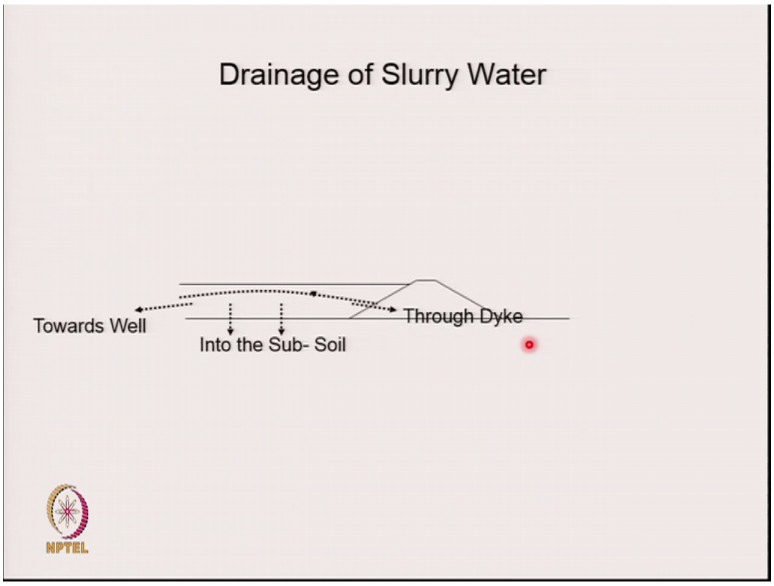

As I did my discharge over the other portion I use to allow this to dry out for six months that is been a standard operating practice. What will happen in six months the slurry water will tend to go down partly it goes through the dyke through the chimney drain bulk of it use to go down because it could seep into ground and some of it go towards the well, but remember the well the lower portion are closed. So, if the lower portion open and there was a filter pack around it, then the water could have been drained out through the well, but at the moment the design is that the lower ports are sealed up as you go higher.

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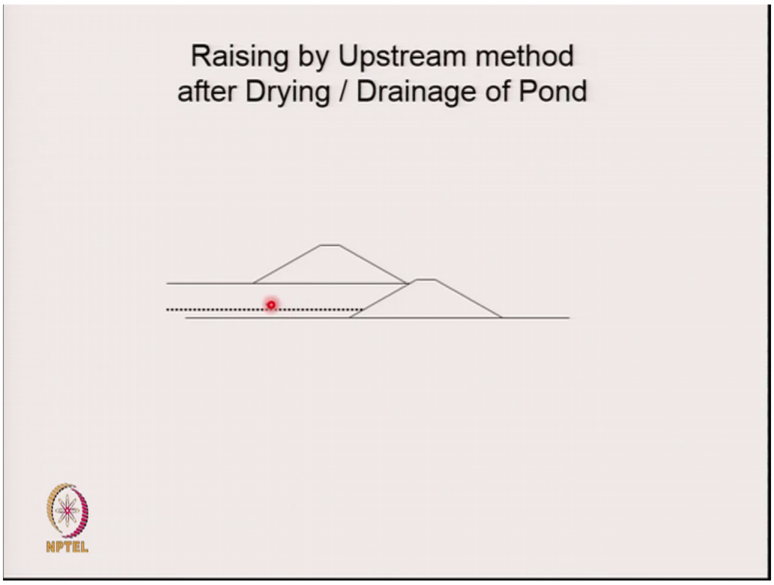

Still after six months when you came what we would normally observe is that the slurry water level inside the ash would have gone down. And this ash would be either moist or dry or this tailings would either be moist or dry when this becomes moist or dry your earth moving equipment can light earth moving equipment can mover this. So, it is possible for you to make the embankment. If this is high then even you cannot stand and even earth moving equipment cannot stand if the water level is near the surface. So, this is the standard method for raising this by the upstream method.

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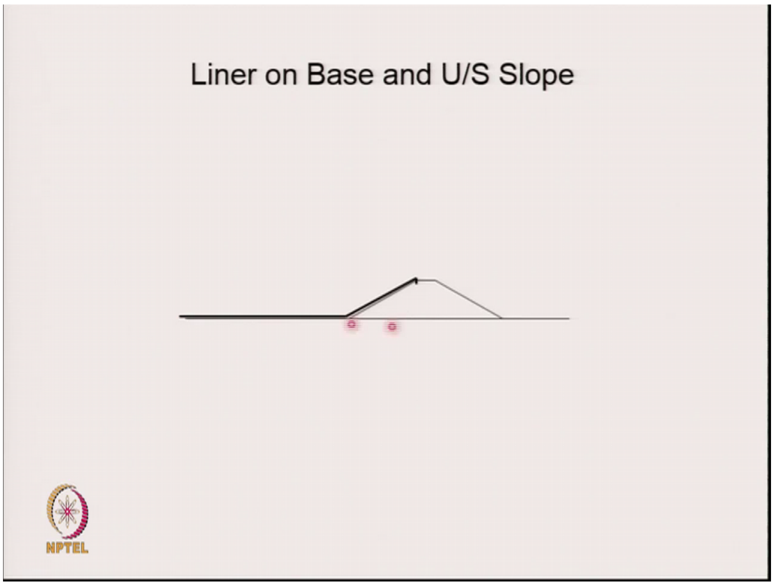

Now, what has happened the government or the regulatory authorities are saying please line the ponds. Conceptually, let us line it, let us make a dyke and lets line the pond.

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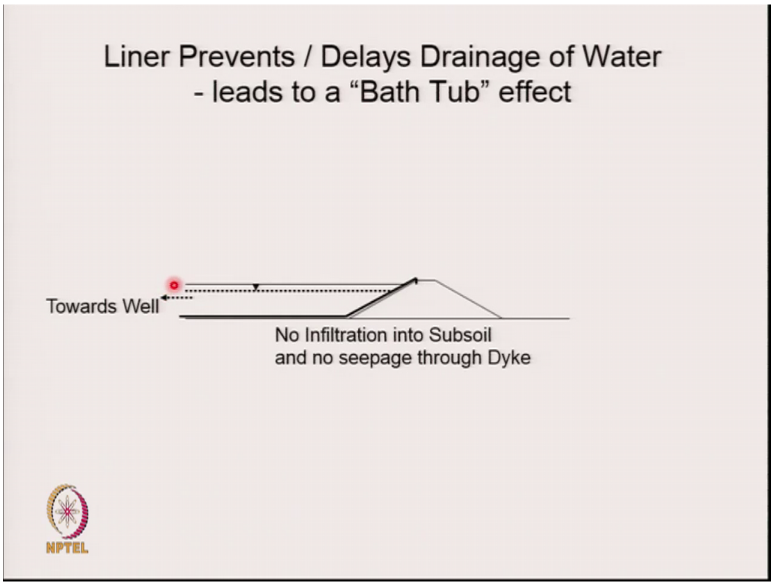

So, how is this good or bad well, you now put your slurry water and in 4-5 years your first raising is full then is ok. Now, 6 months we will allow this, let us move to the next one you start filling the next one and you allow this to 6 months. Where does the water go? Can it go from the through the chimney drain in the dyke no because if you have got an your impervious liner here it is not going to allow the water to drain out? Can it go into the ground, no, because you have a liner at the bottom and impervious this liner may be a compacted clay plus geo membrane. Can it drain out through the well, perhaps if your ports are not properly closed if your ports are closed then the ashes at the top, only overflow water can go in not from the bottom.

So, what you have done is created a bath tub, you created a bath tub and you have plug the drainage. Now, after six months you come and the water is just move down by one meter and you start to construct on it and you have all kinds of problem because though the water has moved down there is some capillary fringe and it sort does not support.

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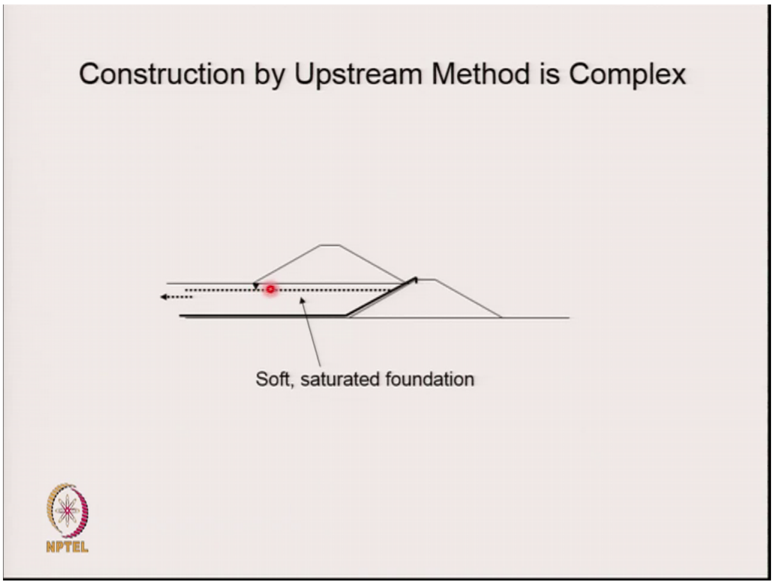

So, you wait a little longer and may be you will do it after in year, but the drainage becomes very, very slow. And constructing on this soft saturated deposit is a big problem, and this is being reported from the field from time to time. Not, only that see what happens later.

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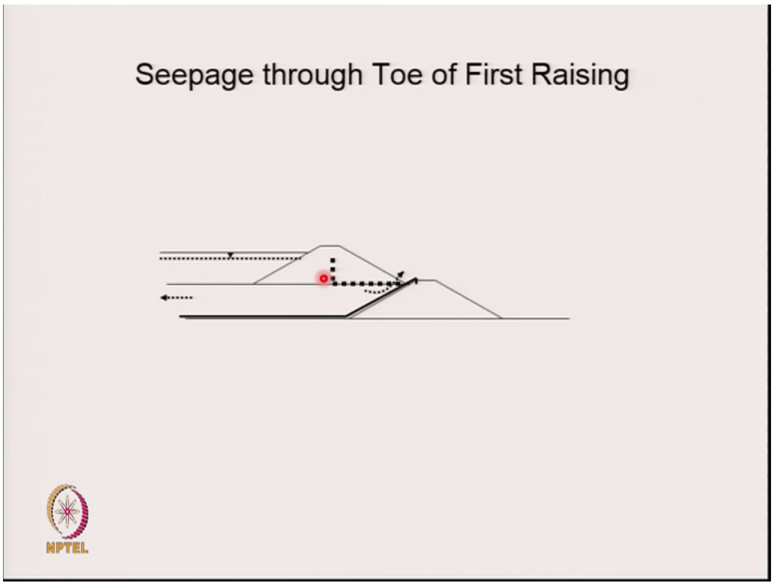

When you fill this pond, now you have made the dyke, and there is a chimney drain, this is the first raising when you say this is the starter dyke, this is the first raising. In the first raising you have a chimney drain now you start filling the slurry again first this slurry water use to go down, it use to go down through this it use to go back. Now, what is happening it cannot go down it cannot go through this. In some cases, it has been reported it starts to ooze out from here from this side. So, in one or two cases, there have been reports of seepage though the toe of the first raising, this dyke has not having any seepage why because the liner is one functional, but this dyke does not have a liner. So, water can come out from this.

So, this starts to create stability problems. So, the only way to put a liner in an slurry pond is also to have bottom drainage you remember your (Refer Time: 29:56) collection layout for landfills. The idea was not to put a liner and have no bottom drainage then you would have a bathtub effect. And even that would drip as I use to tell you that if there is ponding of water on this roof top unless there it is drained out it will drip through even if it is impervious or very low permeability material. The same story here for you to do the next raising, you have to drain out the water, which means two things you must have a bottom drain you must have a drain through this dyke and you must also be allowing then the decantation well the water to come out.

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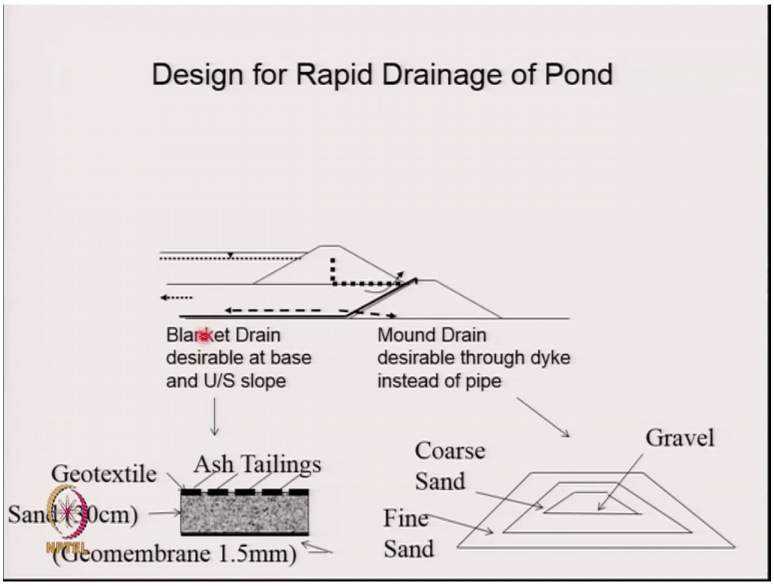

And if I was to now look at this liner it has not been stated in most of the regulatory environment that there should be a bottom drain, but what are we saying is if you have a geomembrane at the bottom then please put a sand layer of 30 centimeters just like your leached collection layer if you recall. And a geotextile filter or a natural filter on top, so that from the ash and the tailings the water will come here and then give it a slope, give it a slope towards the decanting side. If I want to drain it through this, what should I do, if I want to drain out the water through the dyke, what should I do?

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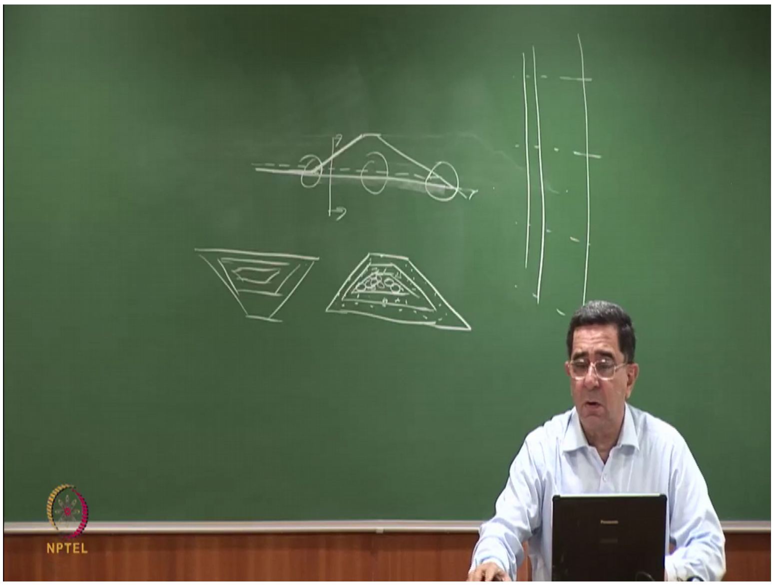

So, let us say this is my dyke and it has a liner. Now, I want to drain out the water I still want the liner to remain in position, then I need to have something which will go through this liner and come out on the downstream side. Simple example is let me put a pipe. If I put a pipe then I can have a toe drain here, and the water can be collected and I can have a rock toe here, but the problem with pipes is with time if there is differential settlement then the pipe can crack. So, one of the ways of doing this is make a drain a trapezoidal drain or we can make a trench drain whatever you want, but the idea is that from here you should be able to carry out clear water.

What is the trapezoidal drain look like, so this will be your drain cobbles and bolders at the center then gravel and then sand. So, it is a flexible drain, it is not like a rigid pipe or a jointed pipe where you can have a problem, here you have a flexible drain. Such a drain this is a cross section here, such a drain would allow your water to pass through it and even if it settles a little bit, it is not going to crack. So, these are all filters around it such that the fine ash or the fine tailings do not come through it. And remember you will need a rock toe here and a filter here, and a toe there. You have a sand layer at the bottom I have already told you that will have to be interconnected to this drain, so that within the embankment if I am now looking at this embankment from the top that is the crest that is the downstream toe at certain locations these drains are coming through to allow the water to drain out.

All that we are saying is if you are putting the liner it should be a bottom drained liner; that means, any liquid which is resting on top either goes to the well in which the bottom most ports still allow water to come through because by putting a gravel pack around them. And you may still allow passage of the drain the water to drain out through the embankment as well by properly designing it. And this is if you want to make the drain bellow the ground then you can make a trench drain. How does a trench drain look like, exactly the opposite of what it looks like here, this is bellow the ground and this is above the ground. So, if this is your ground either you can have a trapezoidal drain or you can make a trench and have a drain either of two, but you would be collecting the fluid there. And this would then be lined because you would have to line this, so that whatever the water is going out you are not suppose to let it go into the ground.

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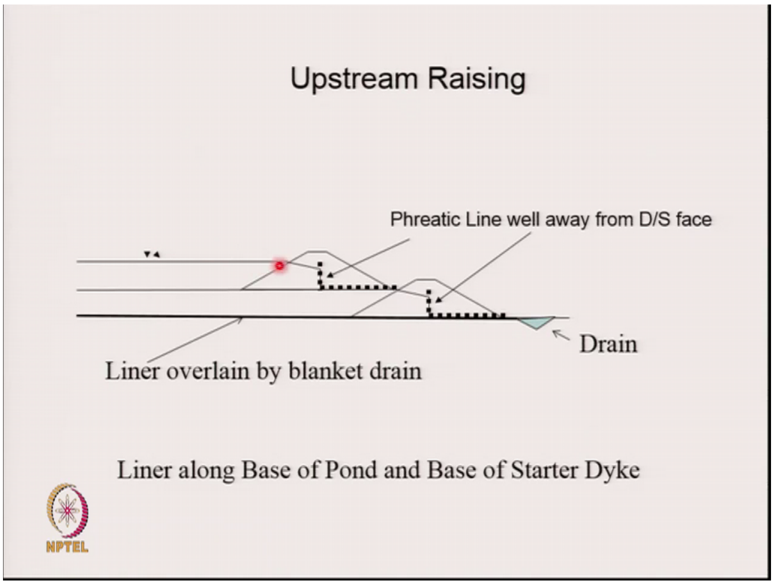

Consequently if you look at the options, so here you see that here what they have done is they have taken the liner overlain by a blanket drain through the dyke. And they have therefore, allowed the water to collect at the drain. In such a case, the ponded water would come down and you would be able to collect make your first raising with no problems.

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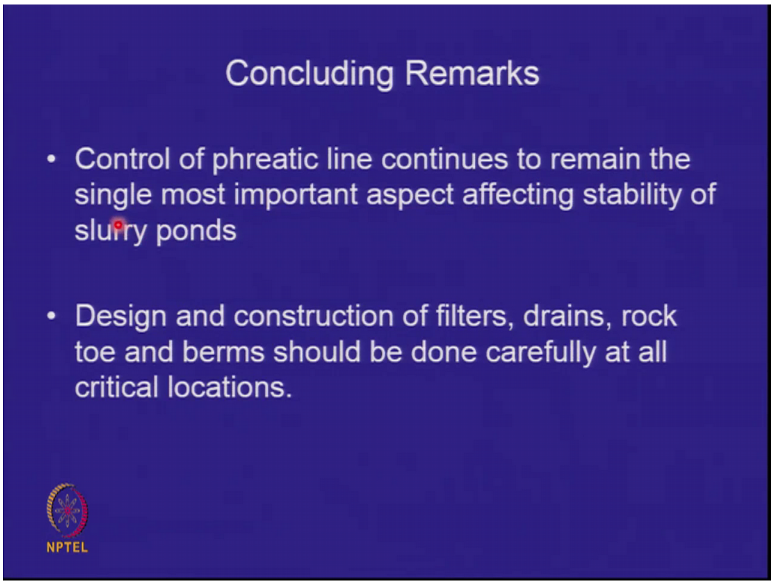

So, control of phreatic line continuous to remain the single most important aspect affecting stability of slurry ponds most of the failures. And in the next lecture, we will be discussing what kind of failures occur and how do you remediate, how do you take remedial action against this failures. Most of the failures occurs because the phreatic line has not been controlled or the filters have not been made properly. And therefore, the fines wash out and the piping take place. Design and construction of filters, drains, rock, toe and berms should be done carefully at all critical locations.

Any person who cuts the corners as a designer on the design of the filters has always face problem of the failure of the upstream method of construction. And why so, because once please understand that both ash and tailings are in the sand silts, silt sand range; they have no coefficient, they highly erodible. So, once the water gets a pathway of coming out it starts to come out and if the fines can also come out then the fines will gradually start to come out and cause piping. And once piping takes place then the rate of flow keeps on accentuating and there is collapse. If water can come out and no fines can come out that is a great control measure for that you have to design these transition filters, so that no fine material can come out of the pond.

So, with this, we will end here. If the any questions, I will be happy to answer or any clarifications that you would like on this topic. But do remember that despite doing everything, we are still putting the upstream embankment on a loosely deposited hydraulic fill. And after the operations are over, let us say thermal power plant is been designed for 35-40 years or a mine is going to work for 50 years, after everything is over no water will come in at the moment slurry. As long it is an operation a lot of slurry water comes in and as long as slurry water comes in there is this problem of stability because you can always have either a piping failure or earthquake induced failure, because it is a soft material. And in slope stability analysis, you will find out that you can always have liquefaction in this silty sand, sand is silt which is not been compacted. So, be careful, keep the phreatic line under control, keep it low or keep it well drained and no fines should come out.

Thank you have a good day.