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

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Lecture – 36
Decantation of Ponds and Stability of Incrementally Raised Embankments Part- 1

Welcome back to this class. Today we will be discussing stability of a incrementally raised embankments. Last time we saw the layout and the water balance and the critical conditions for stability, this time we will go a little more into depth into the stability of embankments. But before we start that there was a one small topic which has over flown, and that is about the decanting arrangement.

Now, we talked last time that the location of the phreatic line is very important. We talked that the location of the phreatic line is very important keep it keep the pondered level as low and then the phreatic line will be low and the stability will be higher, but if the pondered level is high you have a problem.

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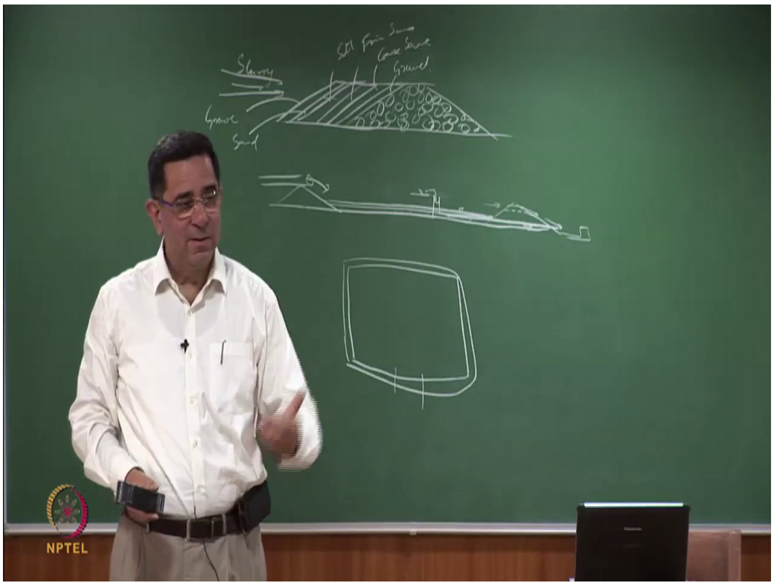

So, let us look at this. I am just looking at the inflow. So, I am throwing in my slurry into a ring impoundment, and I want to take out the supernatant water or the water which is at the top after the solids have settled down. So, give me an arrangement, how will you do that? How will you take out the water from the top, the clear water from the top? When it is coming in it is in the form of a slurry and how will you take out the clear water from the top.

Student: Some kind of trench.

We can I have a spillway, we can have a trench, we can have a something to pump it out. These are some of the options, but we do not want the phreatic line to be high. See one of the one of the ways I can say is let me put an overflow weirs here just a thought let me put an overflow weirs here like a spillway and when the water level comes I can have a whatever, an energy dissipater and I will allow the water to overflow. But that means, I am going to allow the water to reach the crest of the spillway right; that means, I am increasing the water level the fact of the matter is I could have at the moment my deposited slurry was at this level, and the decanting the supernatant fluid was here, I could have So, this is what the material which got deposited.

Let us say this is 6 meters and this is deposited material is 2 meters, and I have half a meter of water on top, I should have removed this water. If I had remove the water the phreatic line would have been low, but we want to operate it like a lake. So, allow the water to fill, and more water to fill, and more water to fill what happens phreatic line rises. So, I need a decanting arrangement which allows the water to come out as the ash settles and the clear water moves up. That is the criticality of design. Otherwise I can always make a well right. So, that whenever when just like you have the overflow weirs I can make a well. That when the water is at this level it will flow into this and go out.

But all these wells with water inflowing from the top or the viewers with the water overflowing from the top they make the water level go up. I actually need something which is moving. Moving means as the ash fills up I allow the water to come out, when the ash rises I move it up. Think it is possible? Let us see how do we decant? Because decanting is critical to low phreatic line, you agree? If I can decant quickly and properly my phreatic line will remain depressed. So, pumps or siphons mounted on floating barges are often used for decanting of ponded water. Sets or I will keep a boat.

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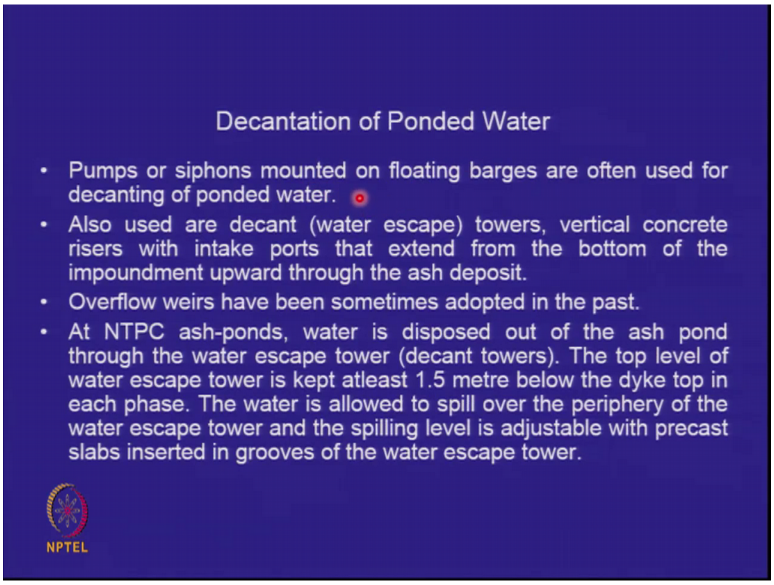

I will have a pump and a pipe wherever I see water I will start sucking it out right. Or all you will have to do is that the boat does not the run aground.

But even if it does run aground you would not you would not be lost you can still reach the end. So, in India this is not used in some of the developed worlds this is used and I will come back to why. So, what we use are basically water escape towers. These are vertical concrete wells or risers with intake ports that extend from the bottom upwards through the ash deposits overflow weirs have been reported sometimes in the past, but not very successful. So, the biggest company which handles ash ponds in and therefore, a large number of slurry ponds maybe it 60, 70 slurry ponds in India is national thermal power corporation.

So, they tend to use this water escape towers called decant towers. And the idea is that the water is allowed to spill over the periphery of the water escape tower into the tower and the this level is adjustable with some kind of a precast slabs or holes I will show you.

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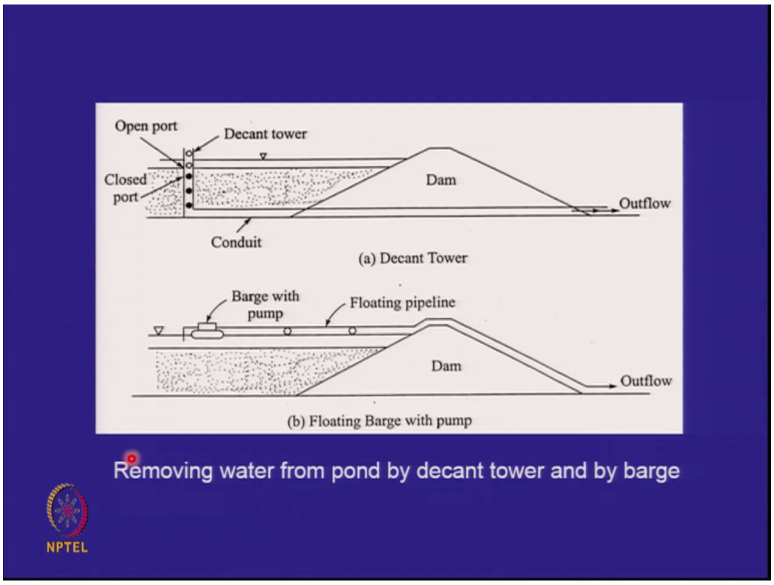

If I have a well or a decant tower which has several holes. Now when I am depositing the slurry here this hole is open. So, the water will go through from here, now the ash has reached this level I will close this port. I will seal it with cement concrete. And then I allow the slurry to deposit more then the water is overflowing from here.

So, the water never comes to the top as long as this deposited slurry level is low, the level of the well is above the deposited slurry level, but is not at the crest of the dam. So, at the moment what you are seeing is that is. So, when was slurry had deposited up to this level this port was open. Now the slurry has deposited up to this level this port is open these are all closed. So, the supernatant water will fall flow fall through this go into the well and go through the dam out. And when the slurry level rises this port will be closed. When the next embankment will be made then the ports will go higher and higher. When the third embankment will be made what will happen? It will sit on top of the well.

So, your well has to be sufficiently back in your design if you are going to have 6 raisings, you can not have a well which comes under the footprint of the perimeter embankment after the second raising and that was something also which was developed from time to time as we went along. So, this is the concept of a barge with the pump that you have a barge which floats around you have a pump which sucks out the water and it goes out through a pipe. The difference between the 2 is this requires no electricity water flow is through gravity this requires luxury it requires power it requires a human being to be around to operate it operate the barge and operate the pump whereas, here you can open a port and go away and come back you know that the slurry level is going to rise after 2 days or 3 days of a week or month, then you come back and close it and open the other port.

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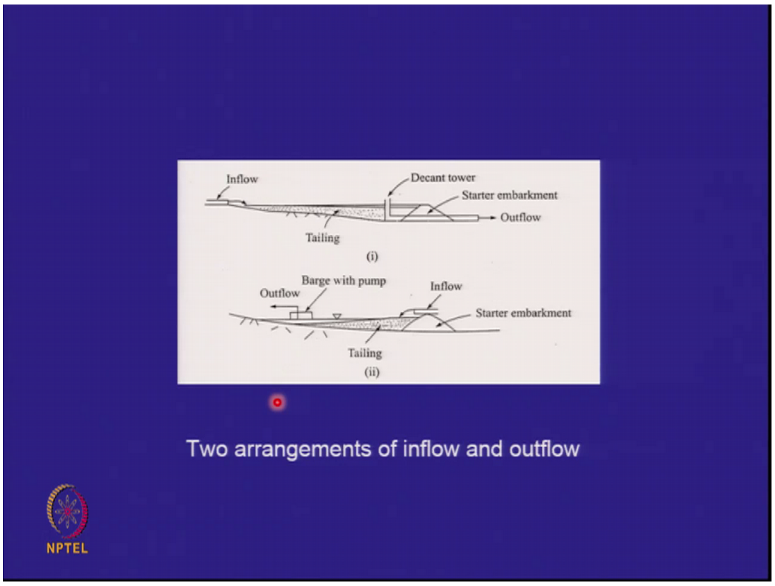

So, these are called fixed location decant towers. These are called mobile barges. And you can see a 2 arrangements here. If this is a side hill impoundment this is the embankment there can be a decant tower here inflow pipeline hear the port is open at this level and the water is flowing out. In the case of a floating barge your inflow can be here water will assemble here and you can pump it out. Now I want you to focus on one aspect which you will discuss as we go along where are the fines getting deposited here and where are the fines getting there. See there is the coarse tailings and the fine tailings or the coarse ash and the fine ash in this condition where is the fine ash or fine tailings getting deposited here or here.

Student: Near (Refer Time: 09:37).

Near the.

Student: (Refer Time: 09:41).

Near the decant tower the outflow zone has the fines. So, remember when you are going to raise this you are going to find underneath. What is happening here? The coarse material is depositing here and the fines will come here. So, the issue always is that you should have coarser material near your embankments and not finer. So, you wherever the decant tower is close to the embankment. That portion becomes problematic you know, you have a ring I just showed you a huge ring impoundment in the ring that decant tower all that one end. So, at the other ends there was garland inflow. So, that is not a problem because this is the beach this is called the beach, and this is called the pounded area the beach always has the coarser material.

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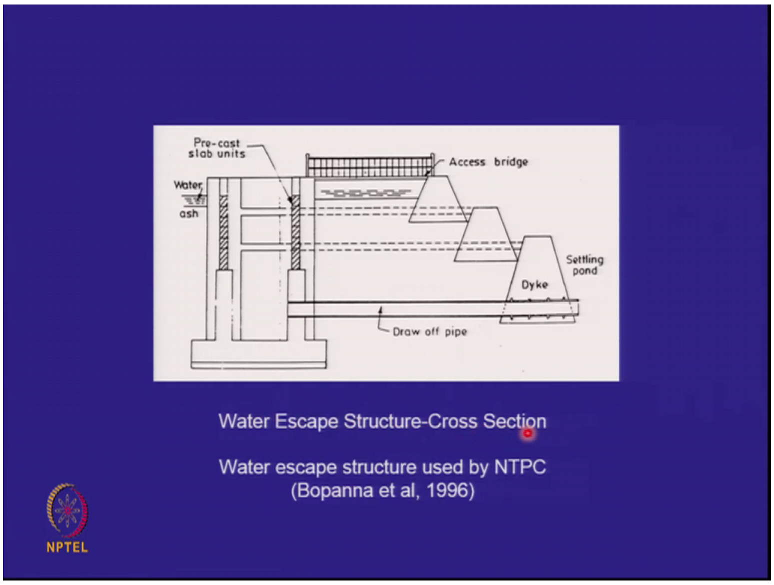

So, in all the places where the inflow pipes are on the garland arrangement they are getting a beach they are having the coarser material, but wherever there is the well there is the finer material and there you have to be careful. Water is high finds them in deposits strength is low material is loose. So, this is the typical design of a an NTPC a water escape structure. Please and note this is vertically exaggerated what this is a dyke, it is their drawing not mine. This dyke slope looks like concrete dyke it is not it is a soil dyke or a ash dyke. So, it will be like that this first phase is starter first raising second raising.

So, they keep the water escape structure far away. And you have an access bridge to it such that at least for 5 raisings it does not get submerged. They do not have ports these are hexagonal in shape.

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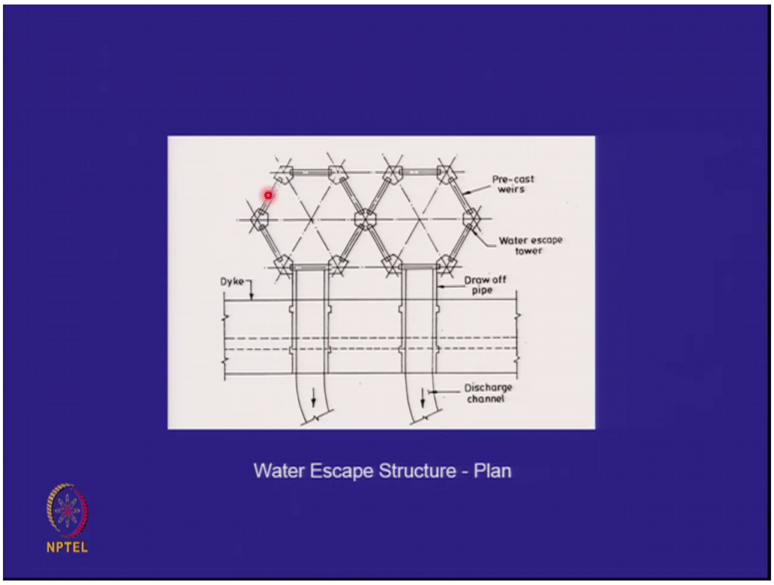

So, this is one water escape structure. They have these precast slabs which can go down grooves I will come back. So, the precast slabs are being placed they continuously be grazed in increments. And when you put the precast slab you send somebody into seal the joints. So, when the slurry is at this level water is overflowing from here then they put the first slab then the second slab and it keeps on going higher and higher like that.

So, this is the water escape structure used by NTPC and this is the dyke. So, below it the water escape pipeline is placed, these are twin structures that have been.

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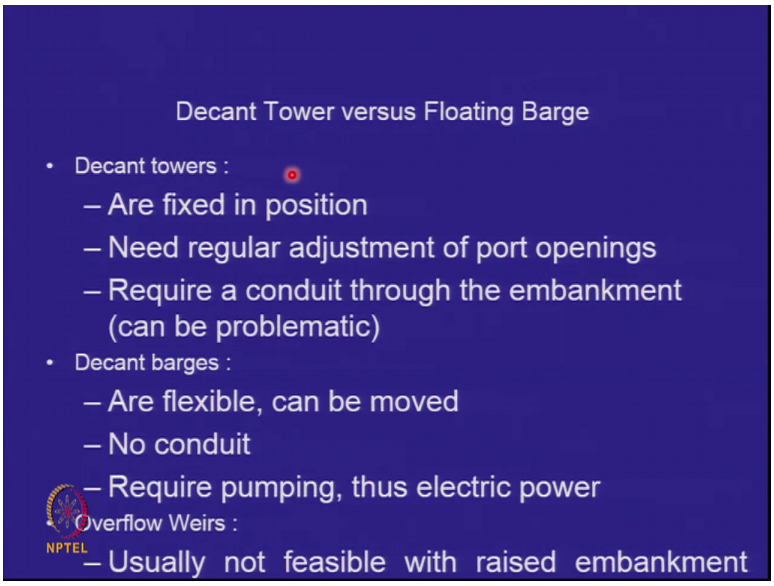

So, these are the precast panels we just keep on raising the weir height. So, the advantages and disadvantages, decant towers are fixed in position. Water is somewhere else and the tower is somewhere else it can happen do not worry why water will go where it wants to go nah depending on the slope of all it got deposited.

So, barge will go after the water of course, unless it is marooned in one corner, in which case also you can get a light barge and pick it up and take it there. So, they are fixed in position and they need regular adjustment of the port openings. They required a conduit through the embankment now you know when we teach earthen rock field dams or earths dams we normally say avoid a rigid element within the embankment, why? Differential settlements are an issue this conduit may be develop a crack if it develops a crack the fines will go through it and then just like we had a photograph today morning you did not discuss it, have you seen the paper?

Student: Yes.

Yes what happened?

Student: (Refer Time: 13:12) Chennai.

What happened in Chennai something happened.

Student: (Refer Time: 13:16).

I do not know. I all I saw was a bus had fallen into a cavity. So, there is a road and the bus is traveling and suddenly there is a gaping cavity; obviously, underground something happened whether it was a tunnel or whether it was a collapse of a pipe sure pipeline. Typically what happens that buried pipe lines in a long term perspective of fifty to hundred years would have some kind of a problems associated with them.

So, we avoid it so, but at the moment we are putting conduit is these are not permanent lakes eventually the pond will become full. After the pond will become full the slurry would not come. There will be no water escaping. So, it is not like a lake or a dam where water is skipping all the time. Decant barges they are flexible and can be moved there is no conduit. So, the base of the dams. So, they look very good, but they require pumping and thus they need power. So, in India we are still using decant towers in the old ponds we had overflow weirs. What was the problem with overflow weirs? As you go up by the upstream method what happens to the overflow weir you can make the overflow weir for the first case. A overflow weir will be like a concrete structure with water overflowing it.

Now, you have moved it back, well you can put your overflow weir back, but the overflow weir will be resting on.

Student: Loose (Refer Time: 14:42).

Loose deposited tailings or ash. So, that will start to have differential cracking. So, you can not make a rigid structure and put it on loose hydraulically deposited materials. So, overflow weirs are virtually out. And many a times this problem has been referred to I ts and we the we have asked been asked can we put a filter embankment; that means, let us have a flexible system. What is a flexible system? I have a ring impoundment I have a ring impoundment and this is my embankment. Let us make this portion a porous embankment, porous embankment means which allows drainage water to flow through it does not allow the ash or the tailings to come out. And see what happens, one can always say all right would you like to make a porous embankment what will you make it off if I ask you to make a porous embankment what would you make it off cross section very porous.

Student: Gravity (Refer Time: 15:51).

Gravel very good. Even you have bothered that gravel may get washed out what is the next step?

Student: (Refer Time: 15:58).

No cobbles let us go to cobbles do not get washed out. In reverse cobbles also come down the river in the monsoons, you are aware that even the rivers come out of hills if you stand on a bridge. In the monsoons you can hear the big cobbles hitting your peers. Dum, dum, we you should go to a bridge which is just downstream of a mountain range coming out into the plains these are rolling down like a debris flow anyways. So, we getting diverted. So, I would like to make my porous embankment of cobbles. I do not want cobbles or boulders. You have done rock field dams, you have earth dams you have earth come rock field dams and you have rock field dams heard about them? Anyways read up about them.

These are dams which allow water to go through them over them, but they are made of rock field. So, sounds good? Now what is the problem? If you make it of cobbles your ash slurry will also come out of it and what else mine tailings will also come out of it because you have large holes in it. So, what will you do? You will now make a filter. The material which is coming is ash slurry fines what is the fines? What is the grain size distribution of.

Student: (Refer Time: 17:23).

No total material is silty sand, towards the inflow is here outflow is here what is the material coming in?

Student: (Refer Time: 17:33).

More shield more shield. So, you need a filter between a silt and cobble, oh that is a lot of filters immediately how many number of filters do you think. You would like to put behind the cobble will be gravel behind the gravel will be coarse sand, behind the coarse sand will be fine sand, behind the fine sand will be. So, at least 4 layers you will have to apply the filter criteria of the soggy we all aware of that d 15 and d 85 ratios the two.

So, basically what you are going to do then is to put layers looks good? Should work better than your well, you do not have to wake up in the middle of the night and say oh I had to close this port because you forget to close the port what will happen? Fines will come and the next morning knock, knock, knock central pollution control board people will be at your office and say here look white water white water coming ashy water you said I was sleeping such that is not an explanation and if it is America you will be behind bars yeah, yeah in America they punish you for all the wrong. Because and therefore, you do all things right here we say all right [FL] penalty [FL] port we are closing the port anyways.

So, I have now gravel coarse sand, I am just putting please I do not know whether this is assuming that I am trying to stop fine silt from coming in. I am putting I am I just put silt and then your slurry will come in here. Looks very exciting. This is the solution which we should have. There are 2 problems here. One problem is what is the upstream slope now made of?

Student: (Refer Time: 19:31).

What is this upstream slope made of? What is the problem with silt?

Student: (Refer Time: 19:35).

Firstly you do not get pure silt secondly.

Student: (Refer Time: 19:40).

Yeah erode is again starts to give you dust it starts to get wind gullies. So, you come to a designer like manoj datta and he will say, let us stop this dusting from taking place let us make yet another filter. Sand, gravel how do you like it? Any problems? This is the correct way of having an upstream slope which does not erode. And still has a silt barrier inside which will not allow the fine particles to go through. It does it look sensible or no very expensive. Now the expenses are going up. Anybody would like to punch a hole through this? So, that is my slurry carrying the fines the coarse particles are all settled.

So, what will happen these fines will start to come in, they can not pass through water will pass through and fines will not pass through, agreed? Is a good filter.

Student: (Refer Time: 20:56) choking.

Absolutely, absolutely once they are fine start to settle. And start to clog up your drain. You must have the capacity that what is in flowing must flow out otherwise the water level will rise. So, suppose it chokes it you will say. So, what at least the fines are not going. Then your water level is rising and finally, what will happen? Water will start flowing over from the top and again the fines will come out. So, flexible filters.

Student: um.

Flexible filters have not really worked. We have tried it at 2 locations they worked for a few years and then they started to choke. And now let us go back to the bag filter where we are using bag filters to entrap fly ash you know you have electrostatic precipitators or you can also have bag filters for fine dust collection in various. What are the what happens to a bag filter? In a bag filter through the geotextile the dust plus air goes air goes through and dust settles in traps in the bag filter. After some time the bag gets choked, then what do we do? We can replace it or we can unchoke it, cardio will unchoke it.

Student: (Refer Time: 22:19).

Well, either you back flush or you take some kind of mechanical devices and bang up the bags or vibrate the bag. So, that if there is any material which has formed a thin film on it falls down. So, you have to have a mechanism for unchoking. Where is my choking occurring here? Is it occurring at this gravel sand or silt or fine sand or which what is getting choked, where are the fines? Where is a layer of fines form?

Student: (Refer Time: 22:52).

No the fine silt comes and is held by the silt here. This silt, it will allow the water particles to go through, but it did not allow the fine silt part. So, the fine silt particles come and form a thin film on the silt. Can I unchoke it? We do not have an arrangement; however, if instead of all this I was to make this whole arrangement, but have a geotextile filter. If I was to have a geotextile filter, then I could replace the geotextile filter that is what we are doing in a bag filter. The only thing is that the geotextile filter is progressively getting buried in the slurry which is deposited. Can you see the engineering here. You can come and say sir I would not I do not agree with you I will put a I I I will have cobbles I will have gravel I will have coarse sand I will have fine sand instead of the silt I will put a geotextile filter right. And I will give you a geotextile filter which can remain exposed for the 5 years. Or if you are bothered about it on the geotextile filter you put some cobbles So that your geotextile filter is protected from animals from man from vandalizing right.

So, your silt particles will now come and sit on front of the geotextile filter. Now you want to replace now you know it is not working you want to replace it the problem is it gets buried because the ash level or the tailings level is rising. So, we need to have a chamber which has which is So designed where this filter can be changed with time and So far it is not been developed. So, if any of you want to do it you can always make a design you can patent it you can have a startup, and you can make millions of dollars. Does it excite you? Great I hope one of you will do this, but it is all there conceptually it is it is possible it is doable, but just a filter embankment does not work.

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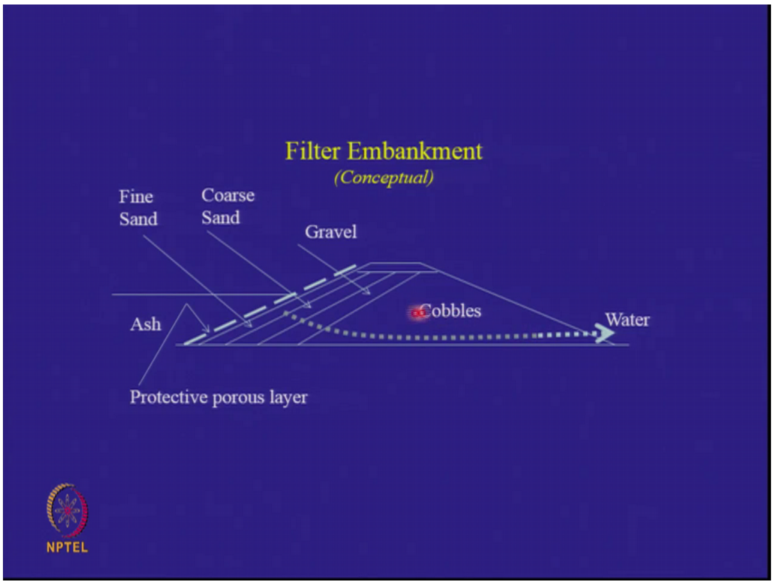

So, what is this diagram which I have put here? I said cobbles gravel coarse sand fine sand. And on top of that there is a dash, dash, dash line that is what you are going to develop that is your patented. So, I have said it is a protective porous layer which will allow the water to go through, but keep the fine ash in position; however, you also have to have a mechanism by which this can be replaced periodically. And this is better than all the other water treatment techniques which are being used which is what if you want to remove a lot of fine suspended solids in water treatment how do you remove them?

Student: (Refer Time: 25:52).

No, no, your drinking water plant, your picked up water from the river total suspended solids are high, what will you do?

Student: (Refer Time: 26:01) sedimentation.

Sedimentation you will have to make a lake.

Student: Rapid sand.

Rapid sand filter. Rapid sand filter catches the suspended solids or catches something else? Everything and what happens to rapid sand filter after a month?

Student: (Refer Time: 26:23).

And what do you do to that?

Student: (Refer Time: 26:26) bag flush.

And then what happens it clogs faster, because when you bag flush it you do not take everything away. You have to change the rapid sand filter. In any of inevitably please understand this problem would then become one in which you should be able to remove the fines, which are clogging or change the geotextile filter. And put a new one or take it away and wash it, and put it back again. After all clogging is a reversible phenomenon it is a reversible mechanical phenomenon, you can backwash it with water or you can back wash it with air.

So much potential that is why I left the word conceptual that one of you well within the next 10, years I will see your name in the papers that you developed such a lovely concept for the various slurry ponds. And believe me every slurry pond when there are high inflows and the pond is almost full; that means, settlement time is not large has a tendency to send out some milky a fluid sometimes. Because this is an open system it is not a closed. The other way to do it is to put coagulants in it. You have a lot of suspended solids you put coagulant So that they all coagulate and they, but look at the amount of chemical being used look at the amount of I mean agent being used for the purpose of coagulation. And then the coagulated particle themselves become contaminated particle why because they are coagulating around a chemical which is not supposed to be there in the environment.

So, this is one of the more critical designs it is not a geotechnical issue, but if you go towards a filter embankment then it is a geotechnical design. And it is a design which is well within your realm of thing able to solve. Any questions any thoughts? I see a lot of excitement, I am encouraged. Let us get back to the stability of incrementally raised embankments. So, if you have got a good decanting system your phreatic line will remain low that is I am saying. Because any system which will allow clear water to come out and not allow water to accumulate in the pond is what we need. At the moment because the water does not become clear the operator keeps on holding the water, it will settle it will settle the more you hold the water the more the pond arises, because the plant can not stop and the mill which is producing the tailings can not stop their work 2007.

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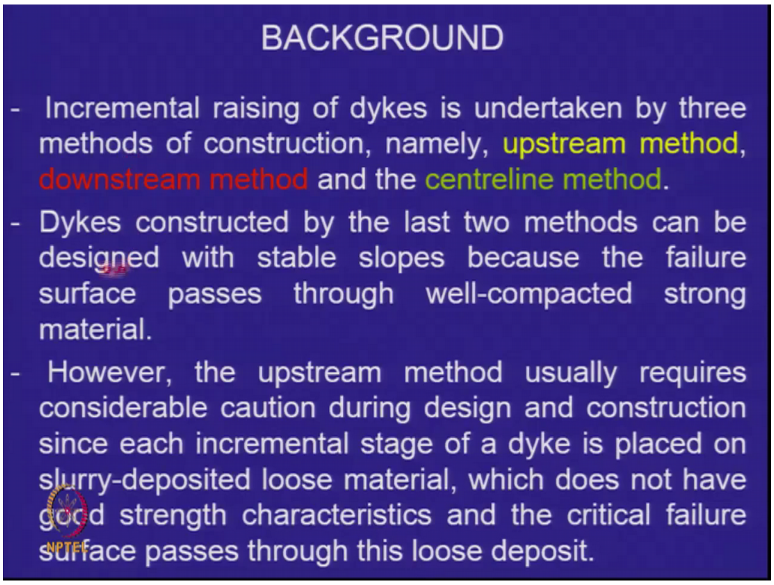

So, and as it rises phreatic line rises. So, as we said we have raising by the upstream method the downstream and the centerline method. When you do downstream and centerline method we have well compacted strong material when you have upstream method you have the problem that you are putting each embankment on slurry deposited lose material. And just quickly recall this.

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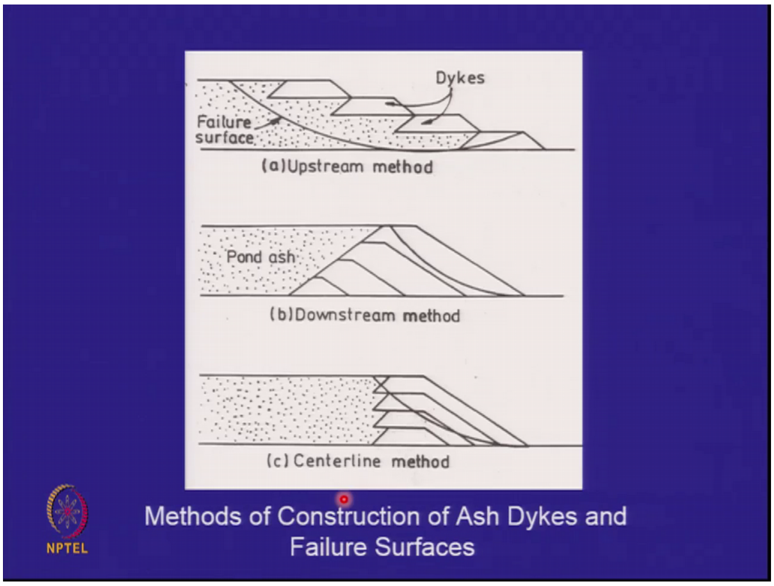

These are the type of failure surfaces that you will get. And in India as I said most of the dykes are being raised by the upstream method of construction.

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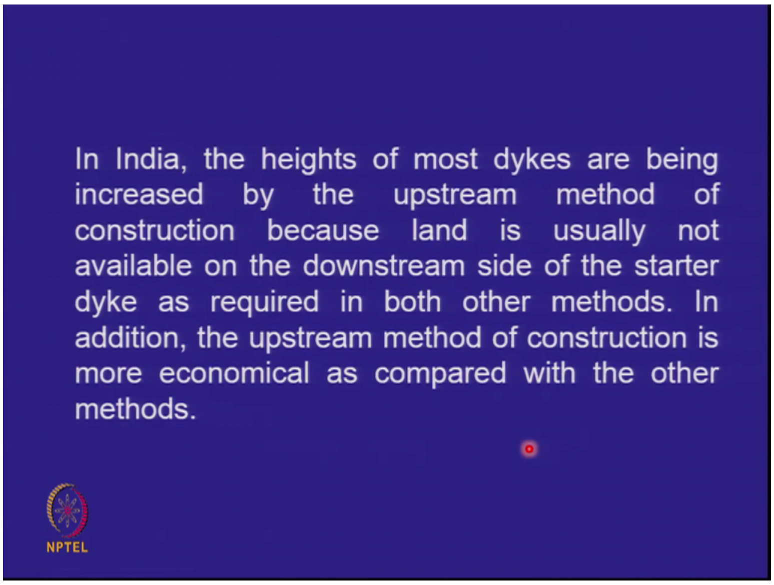

It is because it is more economical and you started at the outer you know, it is very nice to say let us start inside and we will do downstream method of construction.

Now, if there is any population around the tendency is to encroach the land. So, you started inside, but people came and started living around it, then you can not get the land to do your downstream construction. So, if you ask a thermal power station or a mind people he says no first we have to make the embankment at the periphery and put the water inside, why? Then nobody will come and live inside or outside. If you make the perimeter and do not put water inside still they will come and live. So, at one place they said all right we will do downstream method of construction, but let us make a ring bun at the outside, and let us start the construction on the inside. And we will come from the inside to the outside, but what happened? If you only had to walk over a small buns of 2 meters.

So, if you could encroach flat ground you could even close this. And please understand these are not military installations you know you are not having people standing around a people preventing people from squatting, you can not. Your own construction labour your own people start to you know. So, we now come to the stability of this incrementally raised embankment.

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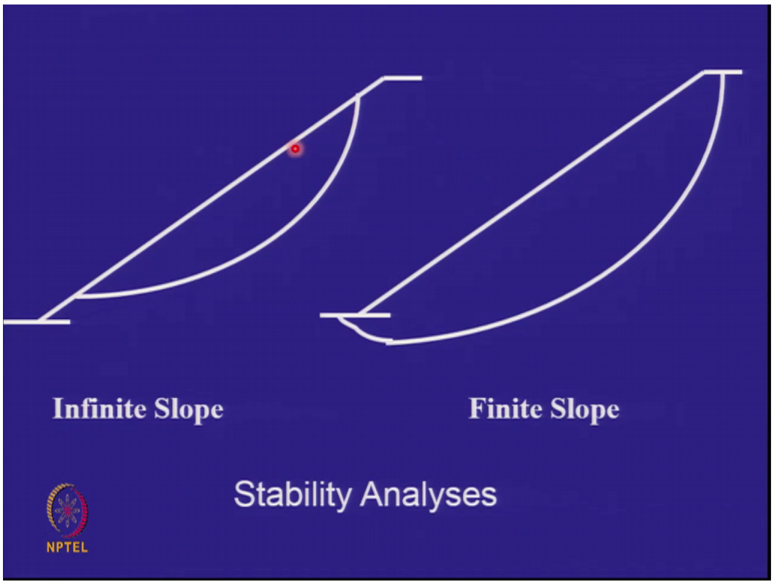

And this is a concept which I discussed last time also the concept of an infinite slope to a finite slope. Do not mind this little aberration you know this should also be a part of the circle, but I made it So that you are you are able to see it and say sir something is wrong in the drawing. The thing which is wrong in the drawing and why I made it like, this was is this a finite slope or an finite slope please tell me. This one it is horizontal at the top horizontal at the bottom? Is it a finite slope or infinite slope? Finite this is about 5 kilometers long, is it finite or infinite?

We discuss this I think briefly when the failure surface does not see the 2 ends. This or this you know if this is 5 kilometers long this thickness must be 2 kilometers there is no such failure surface we exists. So, when the failure surface is a few meters and the slope is a few hundred meters then it would not see the ends. So, this is like an infinite slope analysis. Whether the circle is here or whether the circle is here as long as these do not to ends do not come into play it becomes like a infinite slope analysis. Should we discuss this a little more? It is fundamental to understanding the concept of infinite and finite slope.

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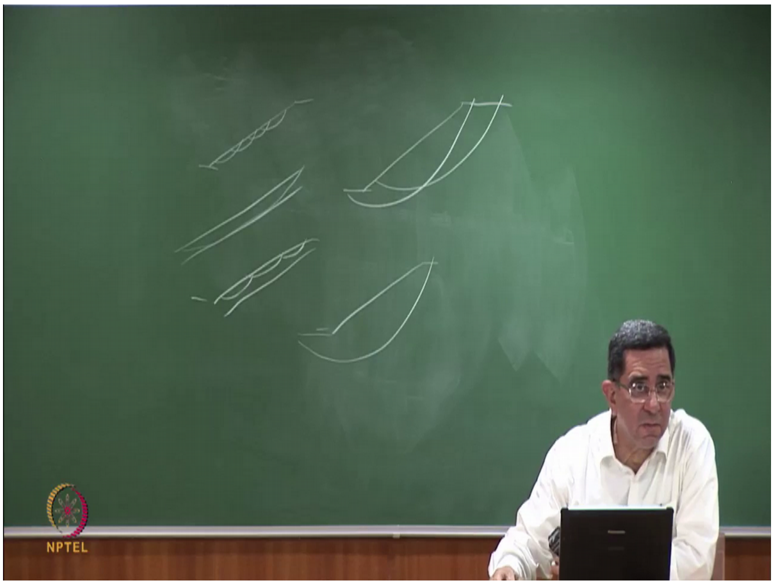

2 slopes identical angles identical diagrams on this blackboard. One is 5 kilo or not still one, let us say one is 1 kilometer long. And one is 20 meters long only difference is in scale that is about it right. And if I have this failure surface or I have this failure surface or I have this failure surface or I have this failure surface, as long as the strength of the material inside is the same all of them are going to give you the same factors of safety, agree? Because they do not see the ends a solid this failure surface is concerned w what is the downward w cos alpha?

Student: (Refer Time: 33:19).

W sin is downward w cos is normal right.

So, w cos tan phi is the resistance and w sin beta or whatever is the driving. So, all of them have identical values, as long as the strength parameters are a constant. So, this is infinite slope for these failure surfaces. Whether this exists or whether it exists here or whether it exists there it does not matter; however, if this is 10 meters high and my failure surface is like this, now when I move this failure surface the factor of safety changes, why? Because the end of end effects are in play. I bring this failure surface here, now it is a different factor of safety, this is a finite slope. And whether it is infinite or finite depends on the depth or the thickness of the failure zone with respect to the height of the slope.

So, typically hill slopes I told you typically hill slope may be hundred meters or more, but there will be a rock somewhere beneath it and therefore, all your failures will be infinite slope failures, because this can not go into the rock whereas, a another hill slope a another soil slope of the ramganga dam how high is it tehri dam.

Student: (Refer Time: 34:46) 220 meters.

I think it is more than 220 meter anyways let us take another dam a earth come rock field dam more than 200 meters high this is this, but here the failure surface can go through the foundation also, depending on whether it is on a soft foundation. So, when the thickness or the depth of the failure surface is comparable to the height of the slope, then you are having a finite slope. This is important for you to understand. Infinite slopes and finite slopes, because once you have infinite slope you have some simple formulae to deal with one when you have when you have infinite slope you have some simple formulae when you have finite slopes you have more complex formulae to deal with.

So, therefore, when you do landslide analysis or when you are doing analysis of hill slopes where the rock is there at 2 or 3 meters depth. Then the surficial failure surfaces are only 2 to 3 meters deep and the hill is a hundred meters high, then you have an infinite slope analysis. Whereas, an earth dam of hundred meters high which has no rock above or below is going to be a finite slope analysis.

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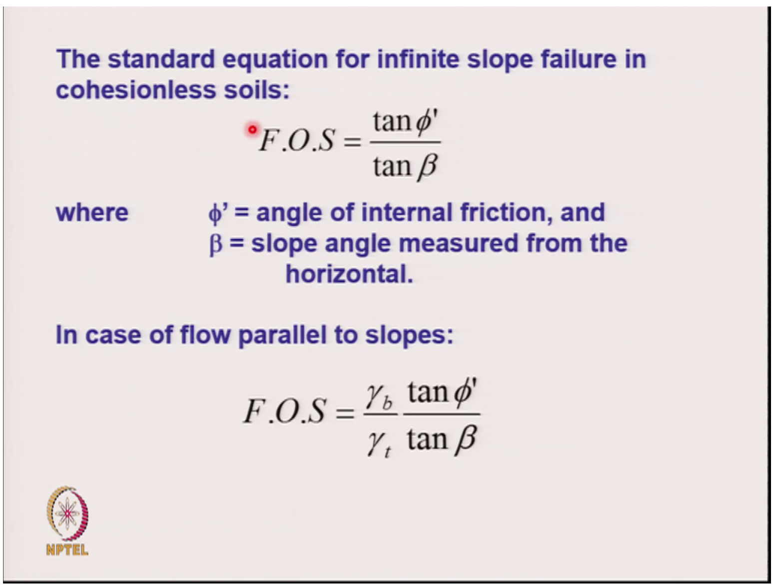

So when you have infinite slope analysis just for simplification of things in cohesionless soil because for us ash and tailings are cohesionless c dash is 0 then. So, nice equation comes, factor of safety is equal to tan phi dash by tan beta. Is this developed is this equation for a circle of failure surface or a straight line failure surface?

Student: (Refer Time: 06:00).

Straight line failure surface parallel to the auto slope you remember. So, is that valid I am showing you circular and here I am talking a formula which are.

Student: (Refer Time: 36:40).

So, when I increase the radius very high, when I increase the radius very high I just want to finish this issue, that this is my limited depth to which the failure can take place I can put my center of rotation very far. When I put my center of rotation very far, then it is almost failure surface parallel to the auto slope, these 2 edges are too small and it is almost like. So, in a sense in a sense for infinite slopes in cohesionless materials, you can use this formula and say this is the formula for a circular failure surface with infinite radius. A circular failure surface with infinite radius will be a straight line perhaps.

So, I have this and when flow occurs parallel to the slope I have this, agreed? We have done this flow occurs parallel to the slope. Flow occurs to the parallel to the slope is the same as submerged slope.

Student: (Refer Time: 37:41).

Let me say this is factor of safety for infinite dry slope. Now if I have infinite submerged slope what is the factor of safety, is it this or is it this?

Student: the upper one.

Yeah, whether it is submerged or whether it is dry the formula is the same, maybe under the submerged condition phi dash will change, but do remember only when flow is occurring parallel to the order slope does this come into account.

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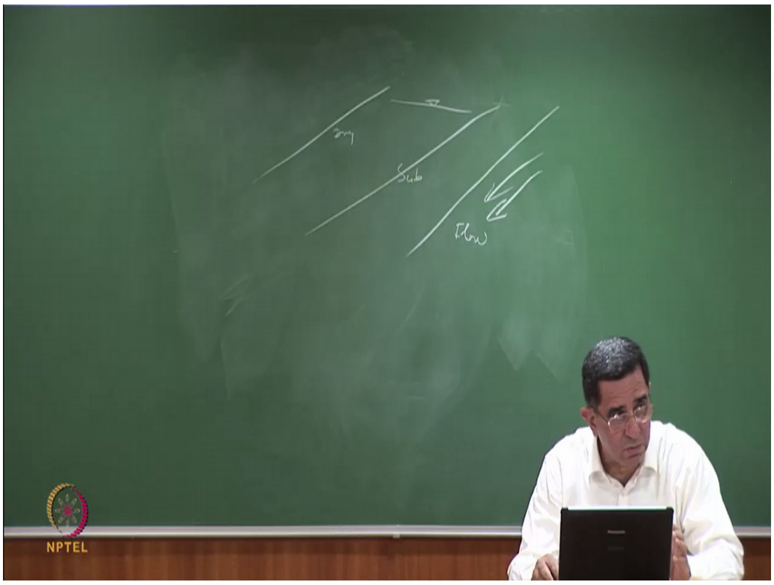

So, again I want to clarify this concept, that I have dry slope I have dry submerged slope; that means, water is there on this side and water is there on the inside and everything is submerged, but there is no flow. And I have dry slope in which water is flowing like this.

So, in these 2 cases this is submerged this is flow. In this 2 cases this tan phi dash by tan beta. It is possible that the submerged soil may have a different phi dash by a few degrees if it is in sometimes phi dash dry may be 35 and phi dash saturated maybe thirty 2 thirty 3 not necessarily. So, sometimes they are identical, but that is a on accrual on the difference in the phi dash here the factor of safety becomes gamma b by gamma t.

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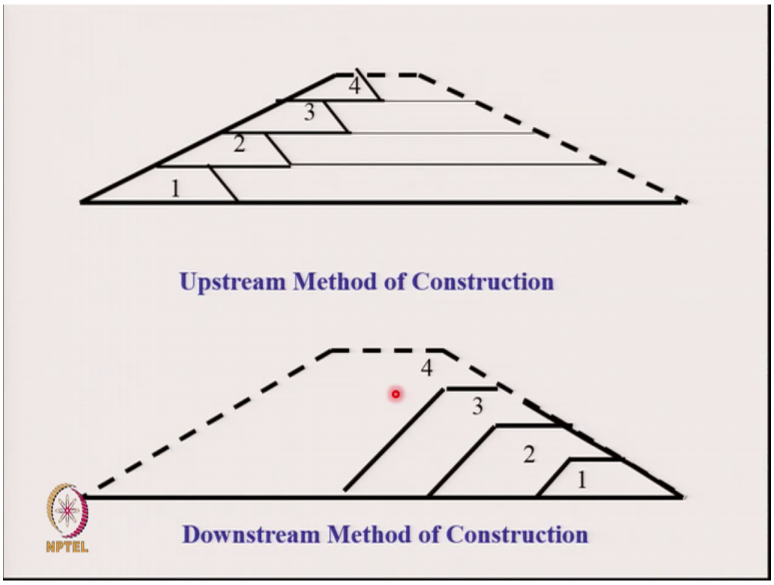

So, these are the formulae which we use for the purpose of understanding infinite slopes. When we apply them to ponds, I just want to bring that photograph.

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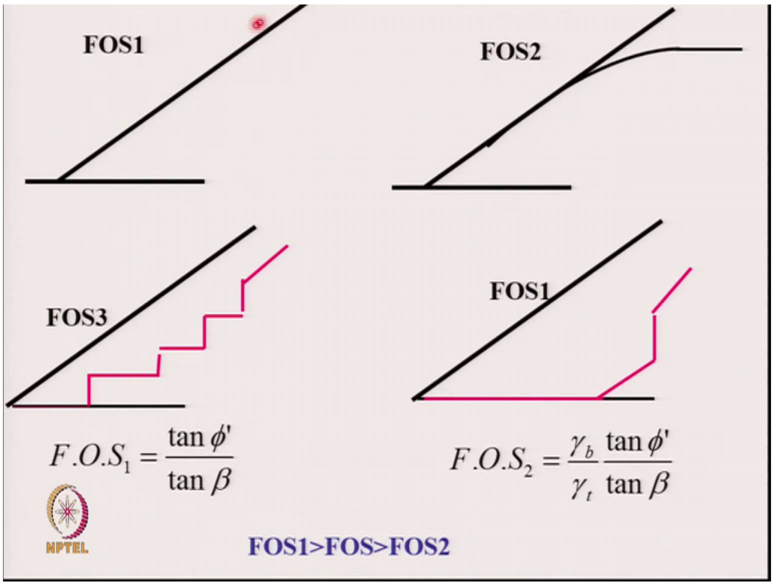

When we apply them to ponds which are finite slopes. I will look at dry slope, I will look at a dry slope with no internal drain then the phreatic surface will be like this. Here you will see it is flow acting downwards. I will have a formula for this and I have a formula for this. And when I put internal drains this phreatic surface will go backwards. So, do remember that our factor of safety is between the dry case and the flow parallel case.

And the further away I can take this phreatic line from the downstream surface, the better is my factor of safety right.

And we will stop this discussion here today, but all I have been trying to tell you is the further you keep the phreatic surface the lower you keep the phreatic line the better the stability. The higher the ponded level the closer the phreatic surface, between a downstream method of construction and upstream method of construction which has a phreatic line which is higher. Both have got internal drains which will have a phreatic line, Which is closer to the order surface?

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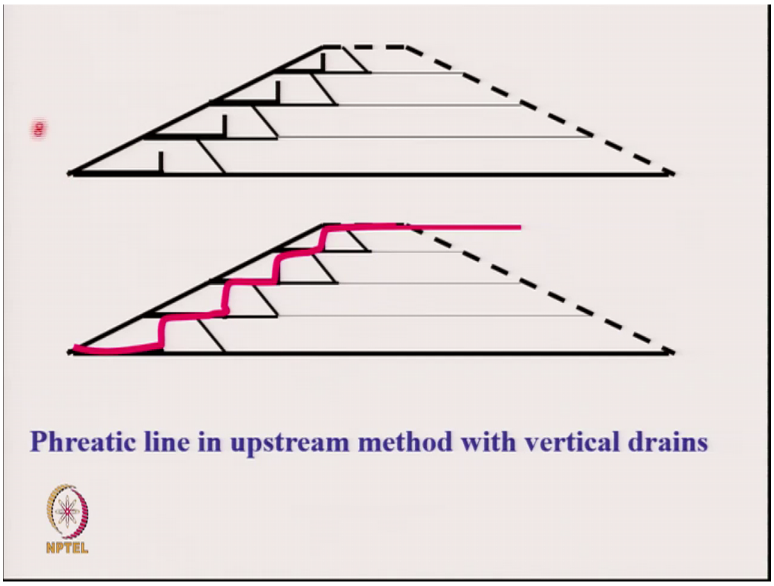

Let us just look at it. This is my upstream method of construction right. And my water is full here it will come like this.

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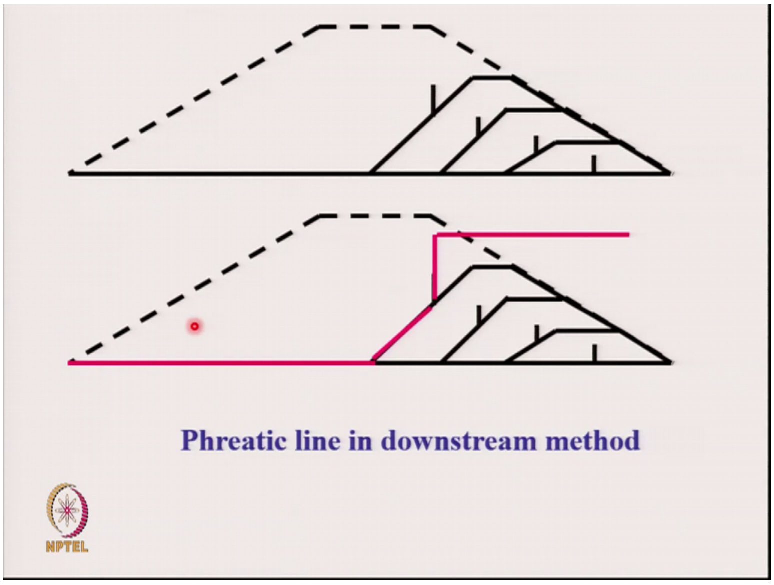

Very close to the outer surface this is my downstream method of construction, and my drain is like this and water is being taken out.

So, whenever the water comes it is caught by this drain. So, it is far away from the downstream slope. So, in downstream method of construction the phreatic line is far away. In the upstream method of construction you can make a very nice chimney drain, but the phreatic line is still pretty close to the downstream face. So, this factor of safety is not as high as in the downstream case. We will stop here today. And we will take up this discussion in more detail in the next class. Any questions? Which come to your mind which you feel with which you feel to discuss and also the fact that are you going to develop the next decanting arrangement, 2 g 3 g 4 g. So, we started with the weir 1 g then we came to the tower 2 g then we came to the bar 3 g we are looking for some 4 g 5 g solutions. Anybody up to the task? I leave the thought with you.

We will take up this discussion in the next class, all the best.