Physico-Chemical Processes for Wastewater Treatment

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Lecture 24

Settling and Sedimentation – III

Good day everyone and welcome to these lectures which are there for Physico Chemical Processes for Wastewater Treatment. And in the previous few lectures we have started discussing regarding the settling and sedimentation. So, today also will be continuing the same in the previous two lectures we discussed regarding how to calculate the terminal velocity under different zones like laminar and turbulent conditions and then transition zones. So, one that once the terminal velocity is determined we can further calculate or design the actual sedimentation basin for discrete settling so that is possible.

And in the previous lecture we found out that along with the terminal velocity certainly the overflow rate is the most important parameter which actually helps in the design of the system. Along with that the horizontal velocity is also very important and the horizontal velocity should also, always be less than the maximum scour velocity of the particles of because of which the resuspension of the particle should not happen.

So, we always try to see that the resuspension of particle can be avoided and we can limit the horizontal velocity within a certain limit so that is there. So, we will go further and discuss this some of the examples will take for further designing the system with respect to discrete settling so that is there. So, some examples are given here like.

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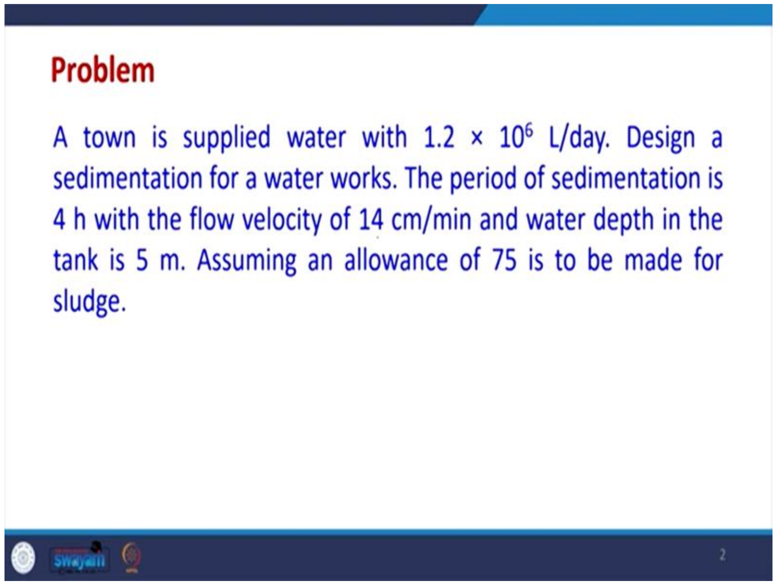

A question is given that, a town is supplied with water which is like 1.2 into 10 raised to 6 liter per day so this much amount of water has to be supplied to a town. We have to design a sedimentation basin for this water works and the period of sedimentation is limited to 4 hour and we can limit the flow velocity up to a certain limit of 14 centimeter per minute so we have already calculated it. And the water depth in the tank can be taken up to a 5 meter so we have limitations so water depth is 5 meter the horizontal velocity is already fixed this is only 14 centimeter per minute.

And the sedimentation detention time we can take maximum is 4 hour. So, and also in the horizontal this overall basin allowance of 75 centimeter is actually has to be done for the sludge so this is there. Now, how much amount of water to be treated that can be treated within that detention period of 4 hour is given here because the flow velocity is already the requirement is liter per day. So, that means we can actually treat only 200-meter cube of water in the 4 hour so this is there.

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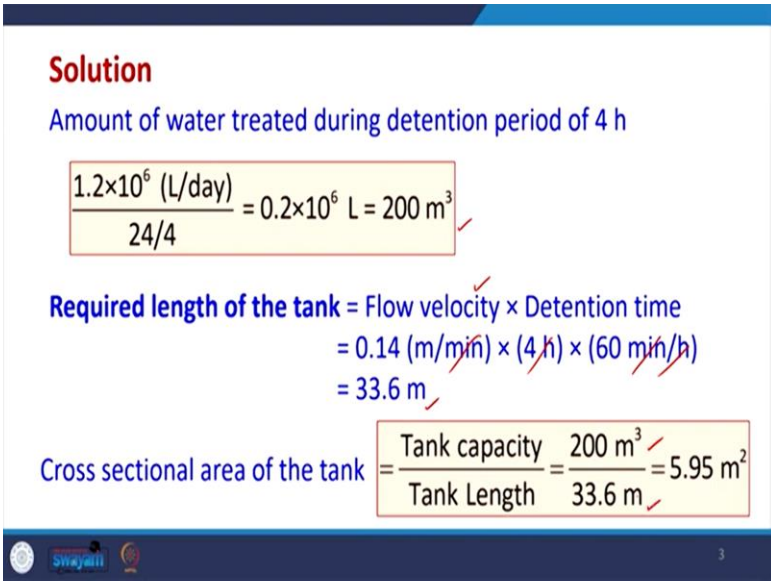

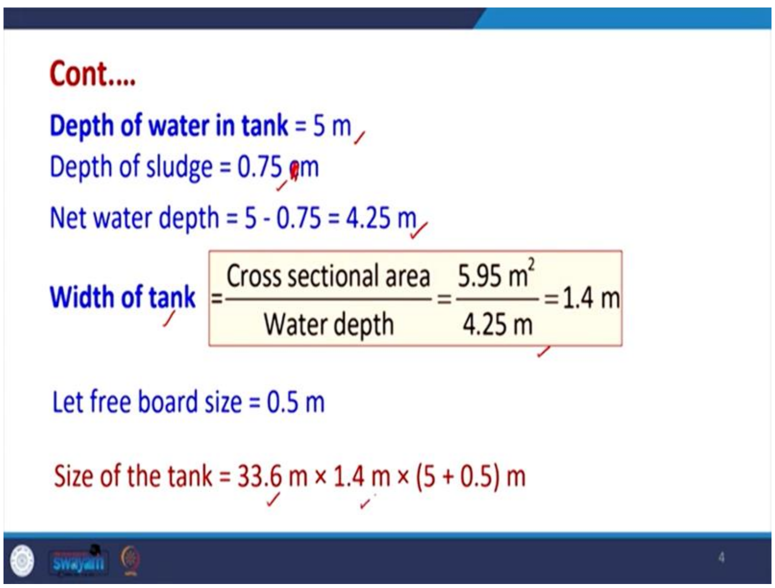

And as the flow velocity is fixed so the required length of the tank can be calculated because the flow velocity is like horizontal velocity. And then the descending time is also fixed 4 hour, so flow velocity multiplied by tension time will give the length of the tank which can which is possible so through this we can find out so here the calculations have been done and all the units can be cut together so it is like 33.6 meter. So, cross-sectional area of the tank now is fixed because the tank capacity is already known we can how much we can treat so 200-meter cube tank length is fixed. So, we have the cross-sectional area of the tank is known to as 4.95 meter square so this is now known.

Now, depth of the tank also we have fixed and depth of the sludge is 0.75 centimeter which is there sorry 0.75 meter which is fixed 75 centimeter and 0.75 meter. So, we can subtract 5 meter minus 0.75 and this is the height that we have actually for water depth net water depth. Now, since cross-sectional area of the is already calculated previously 5.95-meter square we can calculate the width of the tank also and that can be calculated now using this condition and so now 1.4 meter.

So, let the because the already we had calculated the depth as well, so now we are assuming that we have a free board size of 0.5 meter so we are adding that extra to the depth so the size of the tank will become 33.6 into 1.4 meter in the width and 5.5 meter in the height, so that will be the depth overall size of the tank we can use for design of a discrete settling tank which has to be used for supplying water to the any community which is there. Similarly, going further ahead a similar type of question can also be there like the one which is given here.

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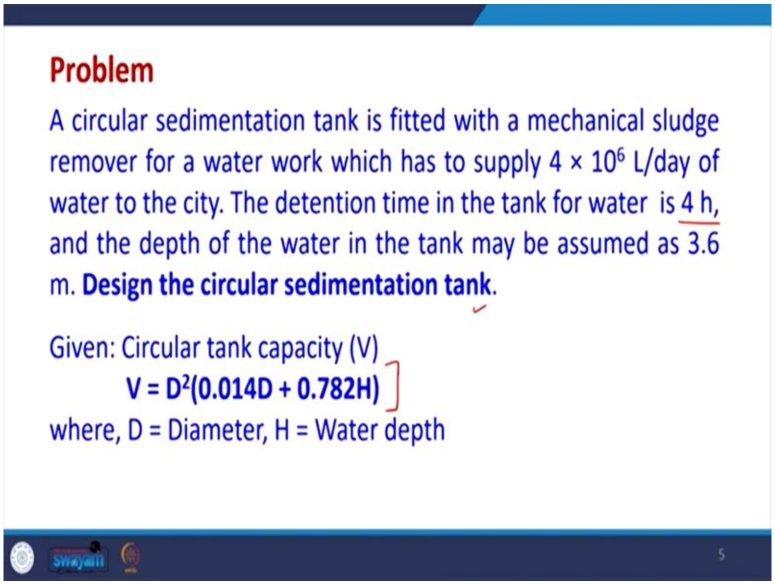

A circular sedimentation tack is to be fitted with a mechanical sludge removal for water works which has a supply of 4 into 10 raise to 6 liter per day in a city. And detention time is again fixed to be 4 hour and the depth of the tank as maximum we can take is around 3.6 meter. So, design we have to design a circular sedimentation tank.

Now, for sedimentary circular sedimentation time we have a one equation which is given here which is empirical in nature so but this equation we can use for solving the problem. And in this equation the volume is related with respect to diameter and the water depth and D is the diameter and H is the water depth so circular tank capacity can be calculated from here so this is there. So, we can use this design equation also and the data is given.

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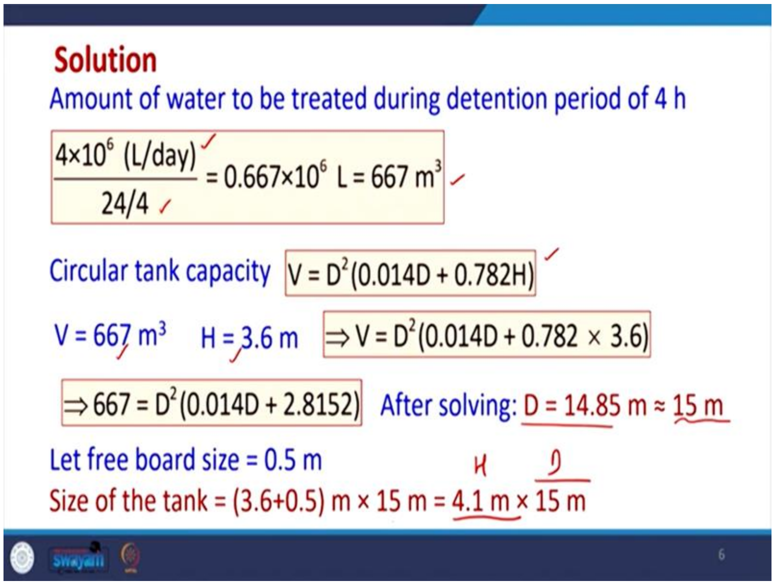

So, like earlier we again further go ahead try to find out that within the detention time of 4 hour how much treatment can be done. So, we have the requirement of water is known retention time is known so we calculate as per that and we found that 667-meter cube of water can be treated in the tank in one go. So, that means the overall volume of the tank has to be 667-meter cube.

Now, we have a circular tank capacity relationship which has been given and height is fixed and the volume is fixed. So, because both are known we can calculate the diameter of the tank also so we can put all the values in this and after solving we get the diameter of the tank which is like equivalent to 15-meter so this is there.

And we assume again we are assuming a freeboard size of 0.5 meter so under that condition the size of the tank becomes like this so 3.6 into 0.5 meter this is the depth and the diameter is 15 meter. So, we cannot keep it like this but it is a tentative idea so size of the tank is like this so this is the diameter of the tank so 15-meter so 4.1 meter is the height and 15 meter is the diameter that we are going to use for designing this particular tank.

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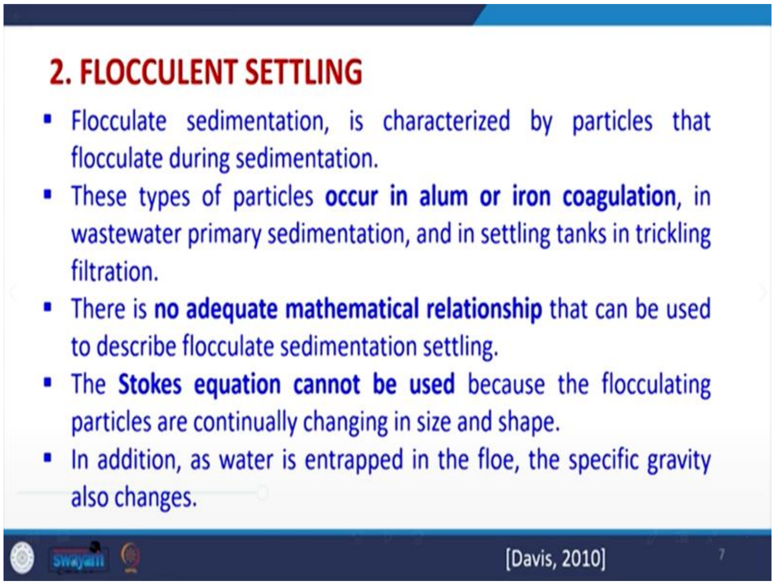

So, up till now what we have done is that we have studied only discrete settling condition. Then there are other settling conditions like flocculant settling then we have hindered settling as well as we have compression settling. Now, we have to design the systems for these conditions also now how to go ahead for the flocculant settling. So, there is some strategies we can directly go for the hand settling for this so approach for flocculant settling also we can adopt the idea with respect to hindered settling or compression settling.

But we can have some other ideas applied here for flocculant settling now what is flocculant settling it is characterized by particles that flocculate during the sedimentation itself. And that will be more when we are adding alum or iron as a coagulant during the coagulation process. So, during the coagulation process and settling there is possibility this that flocculant formation is happening. And because of that so this settling zone is also possible this settling condition is also possible. And this happens when we idle coagulants or flocculants in the settling basin itself.

Now, there is no adequate mathematical relationship directly and stokes equation cannot be used also here directly so what we do is, that we adopt some experimental ideas and from that we can calculate or design these basins so this is there. And so how to go ahead with this we you adopt the method which is given here so what we do is that we take the water and perform lot of laboratory test with settling columns serving as models for understanding the flocculant and settling zone.

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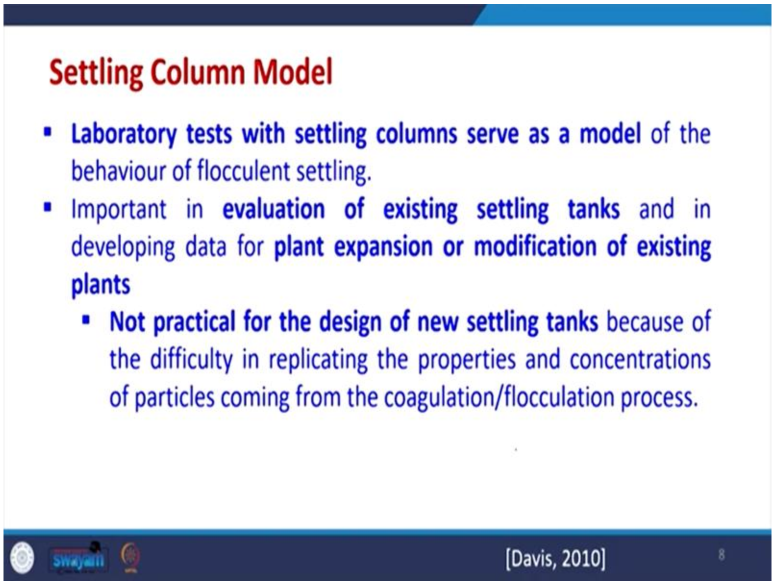

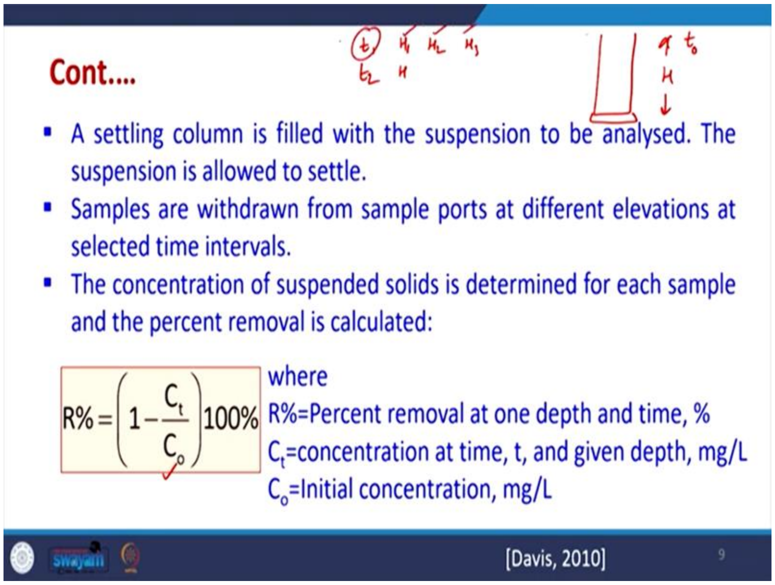

And this method which is we are going to use which is called as like settling column model a similar exactly similar method is used for hindered settling zone also so they are very similar. But here we are discussing the flocculant settling. Now, in this case what we do is that this method which is adopted laboratory test it is more correct if suppose we have to evaluate existing settling tank ok we have to optimize it otherwise. Similarly, if we have to similar water is there and we have to go for plant expansion or otherwise so this is more useful and not very practical for design of new settling tanks it is better to go for the other methods which will some have been discussed some more will be discussed so that is there.

So, now in the settling column method what we do is that we take the water actual water and fill the settling column with the suspension that has to be analyzed. Now, the suspension is allowed to settle down so we have a column in which we fill it and we try to see this because this is a suspension so we try to see that that it is allowed to settle down. And we start measuring the time so at time t is equal to t0 and suppose h is the height of the this particular column. So, what we do is that after some time suppose time t is equal to t1 will try to find out the concentration at height H1 H2 H3 up to the hole depth so that we do.

Similarly, after time t 1 again after time 2 we try to find out the concentrations and these heights. So, we try to find out the concentrations at different heights via withdrawing the sample from the sample poles at different elevations at the selected time intervals. And the concentration of the suspended solid is determined and since we know the initial concentration because we know the initial concentration and the concentration after some time so we can calculate the percentage removal efficiency. So, we can calculate the percentage demo efficiency at various heights at some particular time after that again the second time will be there so we will calculate the removal efficiencies at different times and height.

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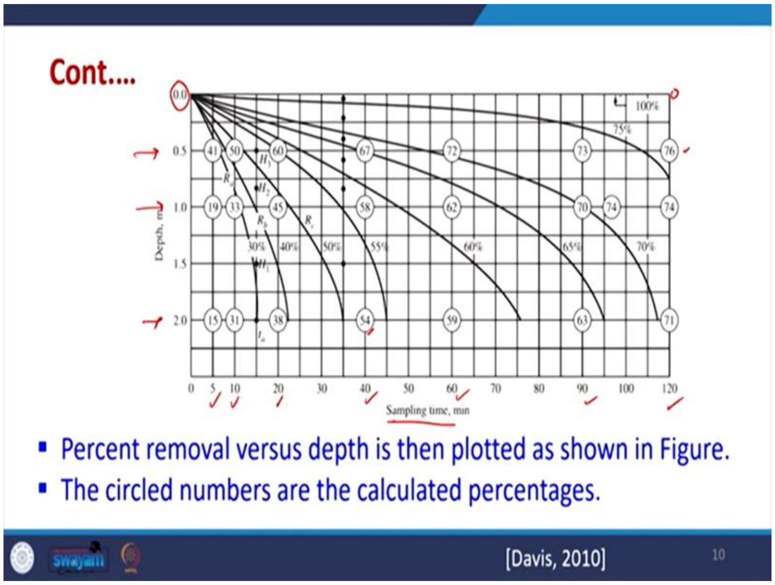

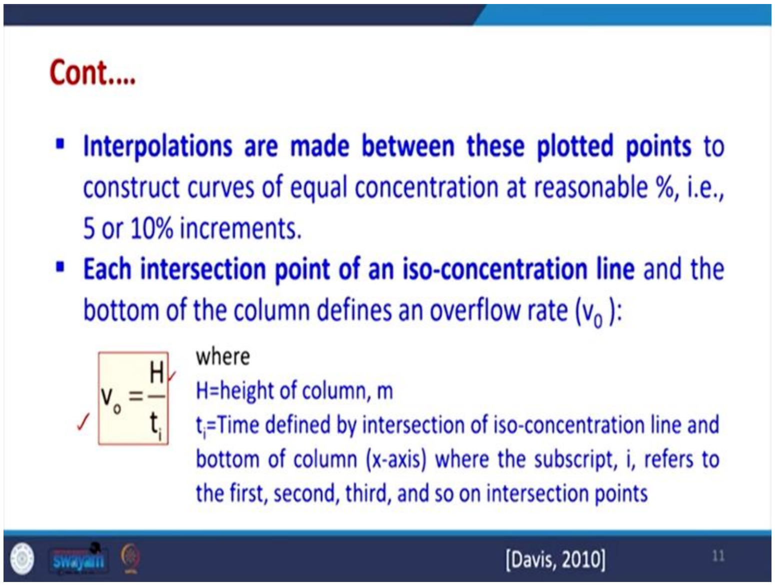

So, this is plotted in this type of graph which is shown here, so this is a typical graph which is used actually for this type of calculations. So, this is here we are assuming that depth to be 0 meter and it is going up to 2-meter so we can draw. And similarly, you can see the sampling time so like for 5 minutes 10 minutes 20 30 up to 120 minutes this has been done. And similarly, height is up to 2-meter so what we see is that we percentage removal versus depth is then plotted as shown in figure the circle number these circle numbers they are the actual removal efficiencies which have been calculated.

So, we can see here that at 2-meter height at 1 meter sorry at 1-meter depth 2-meter depth 0.5-meter depth the values have been calculated at some particular time 0.5 40 minutes 60 minutes 90 minutes 71 minutes so this is how these are plotted. Now, what we do is that this the depth has been taken from bottom up so that we can see here the maximum efficiency is like here. Similarly, the efficiency will be like here 100 percent we are assuming that here the 100 percent removal efficiency is there for with respect to this height.

So, we go further here we try to perform interpolations are made between these plotted points to construct curves of equals concentration at a reasonable increment so this is done. So, and these intersections of points this is called as iso concentration line are iso removal lines. And the bottom of the column defines the overflow rate so this is there and that can be calculated from V0 d into is equal to H1 by so h height of the column is already known but and the time at which this is achieved that is also known so that can be calculated the overflow rate can be calculated.

Now, the iso concentration lines are drawn like this so sometimes it becomes very tricky so sometimes its easier so we have to interpolate in between this is 67 percent and this is 72 percent so and this is 59 so we will see that 59 suppose we have to draw so maybe it will go from here to here 59. So, we will try to see that ok 60 is here so that means iso concentration line may be here so this way we fly try to plot the iso concentration line.

So, which are plotted and this data is helpful in finding number of things and from that we can calculate the overflow rates which are desirable and through which we can calculate. And t is also known here from here we can calculate the time we can calculate the other times with different depth also so this is possible. So, now we perform this calculation we plot this graph and after plotting this graph we can draw lot of conclusions from this.

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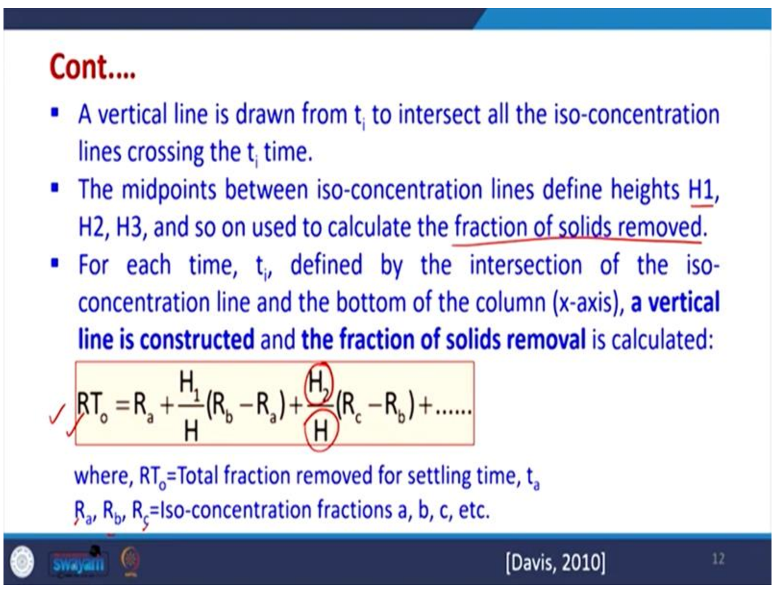

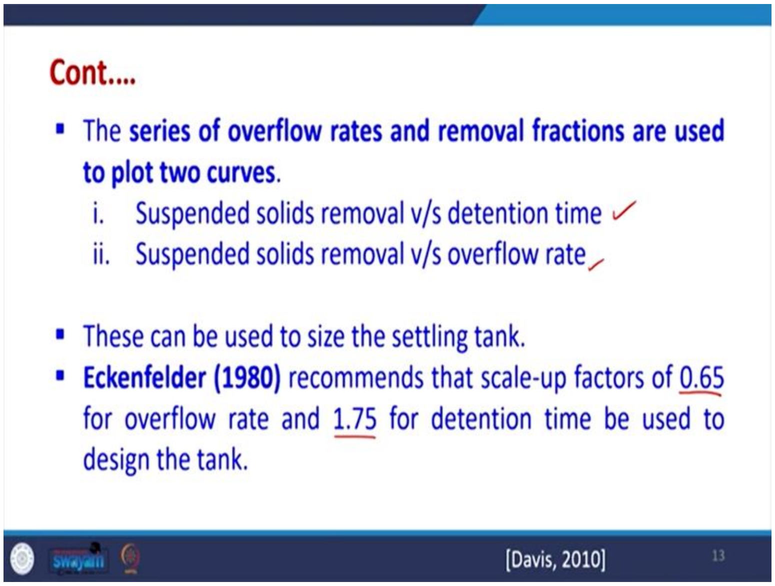

A vertical line is drawn from t1 to intersect all iso concentrations line crossing the time t1 so like here in the here two examples are given like this is one line this is another line which is shown here. So, you can see that this is we can plot like this so we have I this this t1 and H1 both are noted that what is the time at this sorry, time is already fixed this time is known here like this is for 35 minutes so time is known but we know what is the iso concentration line and height at this point iso concentration line and height at this point. So, all these calculations are noted down and from this actually the overflow rate is known and we can calculate lot of things.

Now, the mid points between the iso concentrations line define the height H1 H2 H3 and so on and they are used to calculate the fractions of solids removed. So, from here we are able to see that how much solid has been removed so for each time suppose we calculate for 35. So, for 35 minutes we can calculate this particular that how much amount of the total material will be removed within this time. So, this can be calculated using this particular equation where Ra, Rb and Rc are the iso concentration fractions at these points which have been removed. And then in between we can calculate Rb, Ra will be the maximum which is possible.

And similarly, we can calculate the Rb minus Ra Rc minus Rb and with respect to height that how much height we are going up so that fraction is also taken into account. So, from this we can calculate the total percentage which is possible to be removed from this particular time fraction. And overflow rate is also known so through this we can plot two types of graphs one is like the suspended solids removes versus detention time and similarly suspended solids removed versus overflow rate.

And from these any of these detention time and overflow rate like Eckenfelder has suggested to scale up like 0.65 for overflow rate we can take. Similarly, for detention time we can take little higher detention time like 1.75 of whatever we get and from that we can design the system as earlier. So, these type of graphs are further drawn using some retention time on overflow rate.

Certainly, we have to use the one which is more on safer side and through this we can calculate and perform the all the calculations and then we can design the system. So, this system is true for flocculant settling then there is another type of settling which is possible which is called as hinder settling or compression settling. So, this now we are going to start so in the hindered settling or compression settling these are true for high concentration slurries.

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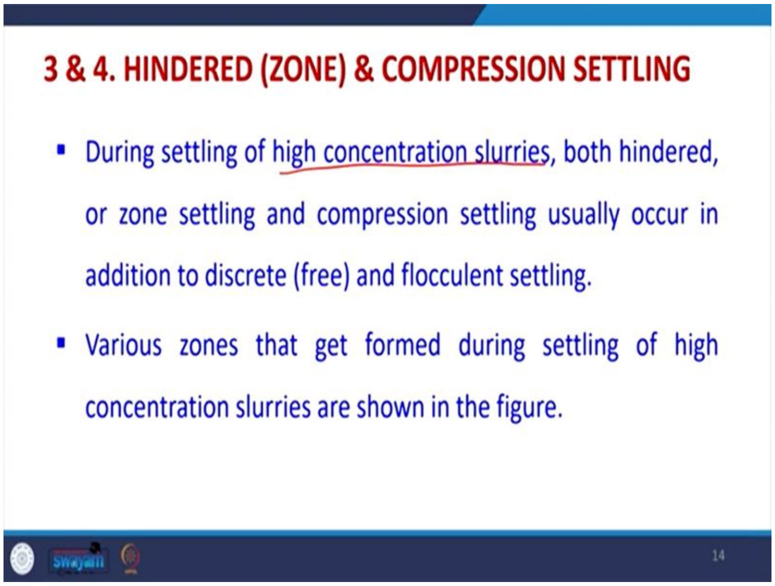

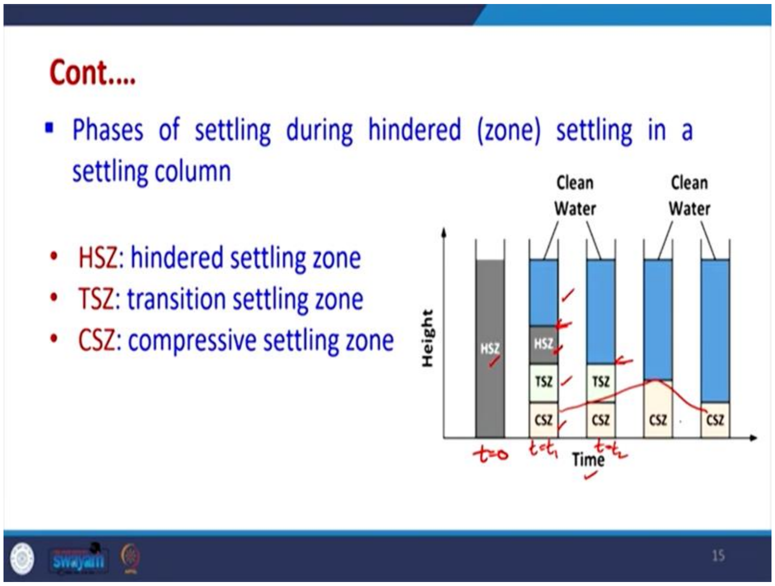

So, where the concentration of solids is very very high so under that condition these hindered and compression settling conditions will occur. And during the settling of such slurries both hindered settling compression settling any type discrete settling and flocculate settling all the settling zones are possible.

So, various zones actually get formed during settling of high concentration ancillaries in any sedimentation basin and that can be described as shown in this figure actually. So, with time actually suppose we have a settling basin or we are performing test in a column in a laboratory. And we take water from actual water which contains very high concentration of the settling material. So, under that condition we suspend it and try to see that where is the clear zone so under that condition we are trying to use.

So, when actually at time t is equal to 0 so this will be the condition whole slurry is properly mixed and we have high concentration slurry and this is like a hindered settling zone where each of the particle is being hindered by the other particle during the settling so this is HSZ. And that has been used using the black ones so there are different phases.

Now, after some time after sometime side like t is equal to t1 will be finding that some of the water will settle down and clearly will be having clean water at the top and after that will be having some will be having solids where at the top of that within that zone there will be three zones one will be having hindered settling zone another is the compression settling zone.

In the compression settling zone what happens is that the concentration of the solid is such high that the overall settling is because of the weight of the solid itself, so that compressive settling zone is possible that will form at the bottom. The good thing with respect to cut compression settling zone is that they are highly compressed and generally we will observe it to increase this zone will increase after some time and then further will decrease after later time. So, this we can see here the height is increasing and then it will decrease but for overall clear water zone will always increase.

So, we can see this zone more as compared to any other zone so we will see that ok most of the solids are below one clear water zone and above that we have clean water or clear water and below that we will be having water which contains lot of solids so we have transition settling zone compression and hindered settling zone. After some time will be finding that the hindered settling zone will be totally removed we have only transition settling zone and compression settling zone and, in the compression setting zone it is the settling is because of the weight of the solids within that zone itself.

After sometime this transition settling zone will also get removed will be having only compression settling zone. And this compression settling zone will further after some time first it will increase and then it will again squeeze down and it will become very less and will be having clean water at the top. So, these all zones hinder settling transition settling compressive settling all different types of zones are possible during the settling of the highly concentration slurry so this is possible. Now, what we do is that we try to perform these type of tests.

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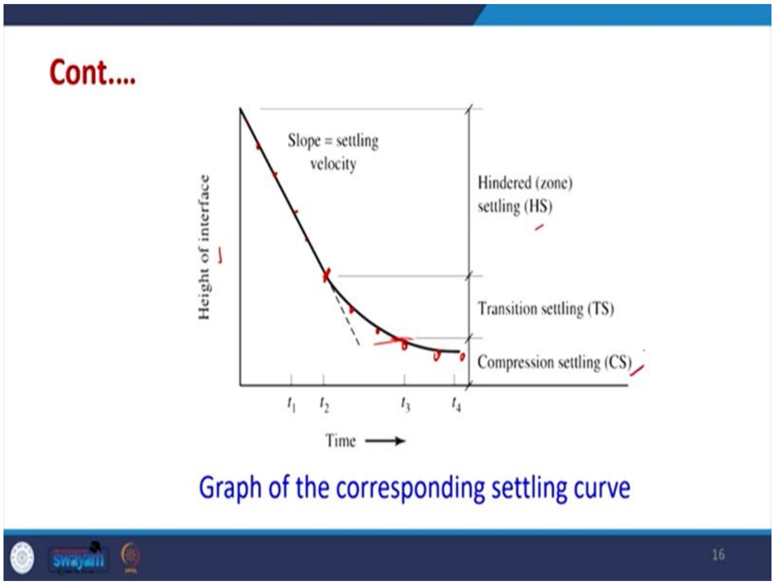

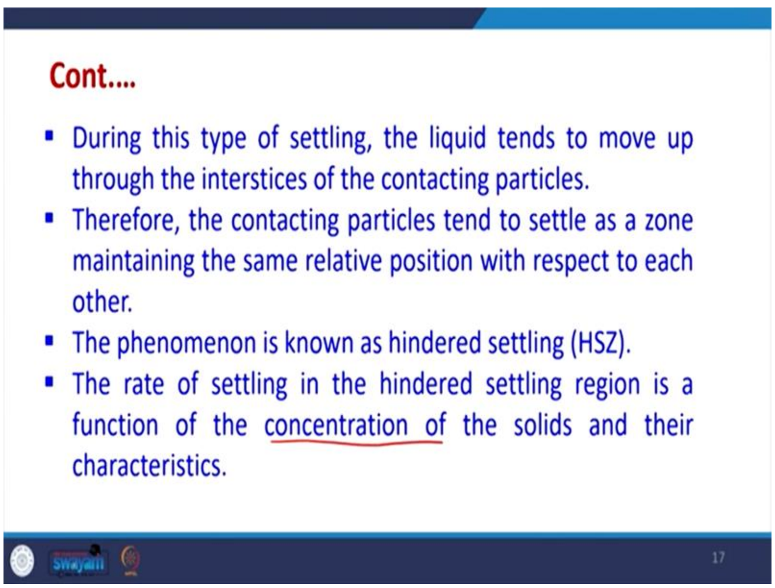

So, for designing such systems we have to perform this type of test and in this test what we do is that we measure the height of the interface where we have a clean settling zone and we have a clean water above that and we have the slurry below that. So, we always measure the height of that interface and we measure the time t1, t2, t3, t 4 et cetera. And from that also we can calculate tentatively what was the hindered settling zone what was the transition settling zone what was that compression settling zone.

So, we try to find out the height will be having points like this height with time and these points will be there like this and we then we plot the graph so up to where up to the point up to which we have uniform like height is decreasing uniformly with respect to time so that is called the hindered settling zone.

In between will be having transitions at link zone after sometime will be having transition settling zone where the compressive settling will increase zone will increase. And after that when the compression settling zone will start decreasing we have totally compressive settling zone that compressive settling that is occurring, so this height is noted down. During this type of settling the liquid tends to move up through the interstices of contacting particles therefore the contacting particles tend to settle as a zone maintaining the same relative position with respect to each other so this is there.

This overall settling that happens in the highly concentrated slurry this is called hindered settling and the rate of settling in the hindered settling region is a function of concentration of solids and their characteristics so both are very important concentration is more important. So, higher the concentration the rate of settling will vary depending upon that, so concentration of solid is very important.

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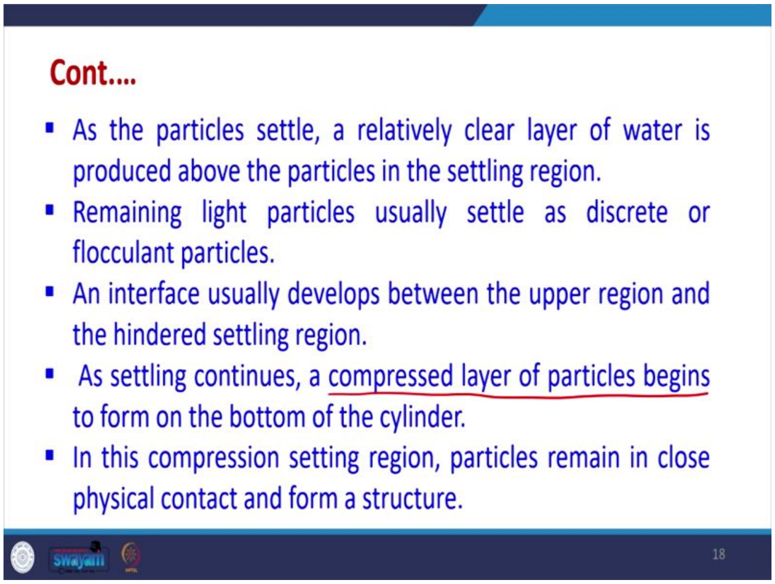

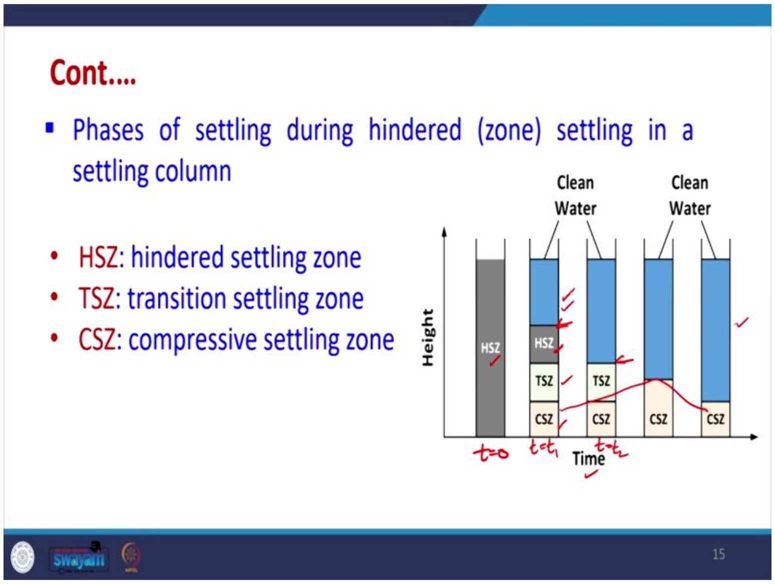

As the particles settle a relatively clear layer of water is produced above the particles in the settling region. So, this is what is shown here you can see a clear water zone is coming out now after that the remaining light particles usually settle as a discrete. So, clear water zone will be there but some discrete particles may be there so that will also settle down with that with after some time.

Then an interface will usually develop between the upper region and the hindered settling region which will be having three zones hindered settling zone transition zone and the compression settling zone. As the settling will continue a compressed layer of particles begins to form at the bottom of the cylinder or the column. And in this compression settling zone particles remain in very close physical contact and form a structure so this is there. And hinder compression settling zone particles remain in the close physical contact and form a structure.

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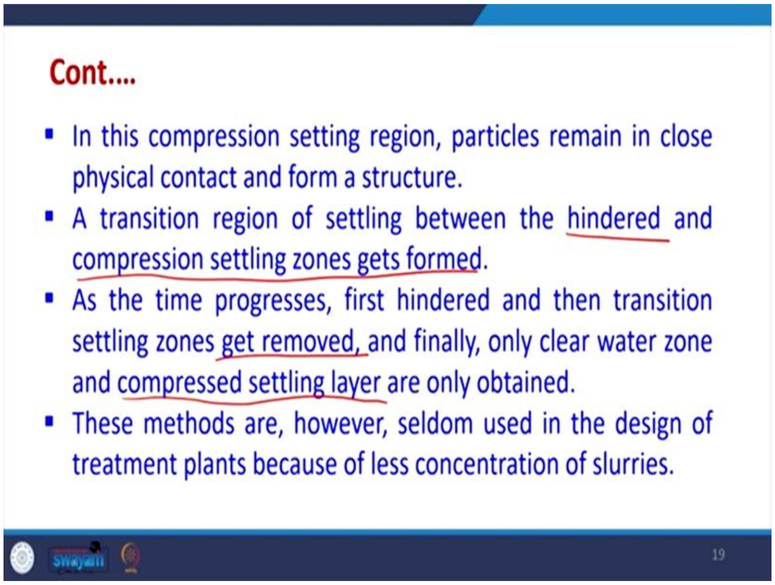

A transition region of settling will get formed between the hindered settling and the compression settling zones and as the time progresses the hindered settling zone and then the transition settling zone both get removed. And finally, only clear water zone and a compressed settling layer will be there and this settling layer will increase up to a certain time after that again will be it will be decreasing. And these so we always try to find out the these type of tests are performed. And from that we try to find out that how much area is required for compression how much area is required for thickening etcetera. And from these data we can get lot of the calculation we can perform.

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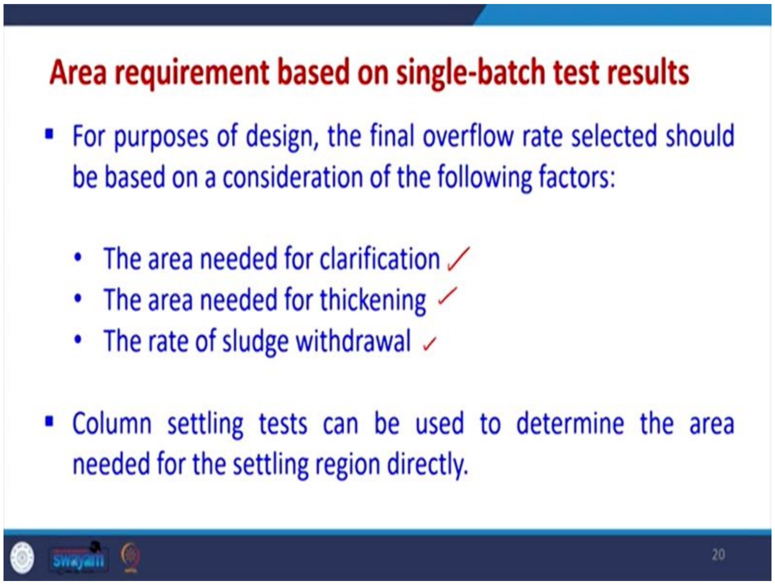

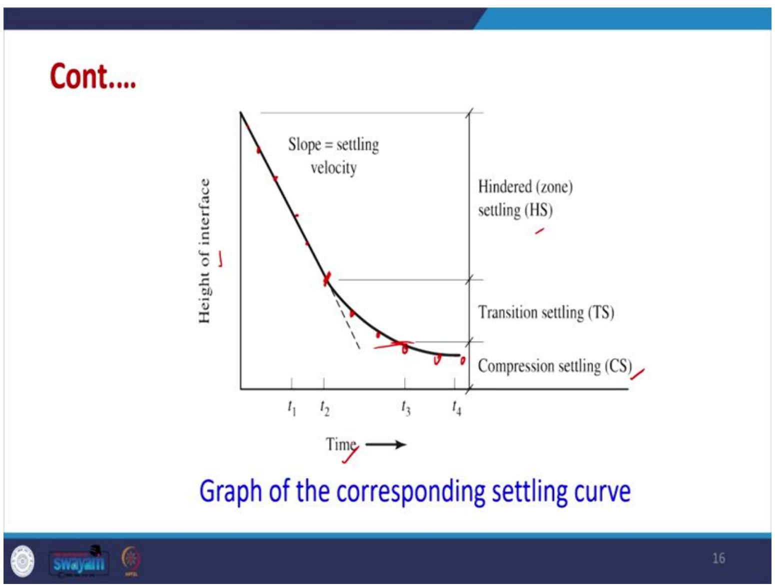

So, all these areas required for clarification area required for thickening area the rate of sludge withdrawal all can be calculated using the height versus thickening data. So, this is height versus settling time data. So, now today we will end the lecture with this will continue with this curve in the next lecture and from that we will try to find out the area of clarification area of thickening how this can be used for finding all those parameters and then among those parameters which is whichever area is higher so that area is used for actually designing a sedimentation basin where hinders settling zone or where hindered settling is more occurring as compared to discrete settling.

So, will continue in the next lecture with the design of a settler where actually the hindered settling or compression settling is occurring and that will be true for highly concentrated slurry in any condition. So, with this will end will start the next lecture with this graph itself and further understand the procedure so thank you very much.