Physico-Chemical Processes for Wastewater Treatment
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Lecture 25
Settling and Sedimentation – IV

Good day everyone and welcome to this lecture on Physico Chemical Processes for Wastewater Treatment. And will continue with the settling and sedimentation lectures that we learned little bit regarding them in the previous lectures, now we will continue with the same. So, in the previous lectures we started with determining the terminal velocity or settling velocity of the particles in a discrete system. Thereafter, we find that that how we can use that terminal velocity along with the overflow rate to design a sedimentation basin for discrete system. Now, there is other types of settling behaviors which are possible one is like flocculant settling.

So, in the previous lectures we studied regarding the flocculant settling and we understood that there is a column test by which we can design a system for flocculate settling also for that actually we that system which exist that is true for only existing treatment facility suppose we have to upgrade it or otherwise.

Now, if we have to go for other type of systems where suppose compressive settling is occurring or where hindered settling is occurring. Then we learn regarding the conditions in which high concentration slurries may settle as a hindered or compression settling conditions. And under those conditions we also learn little bit regarding a method in which the experiments can be performed in the lab and we can that data can be used for designing a sedimentation tank for the conditions where high concentration slurries are there.

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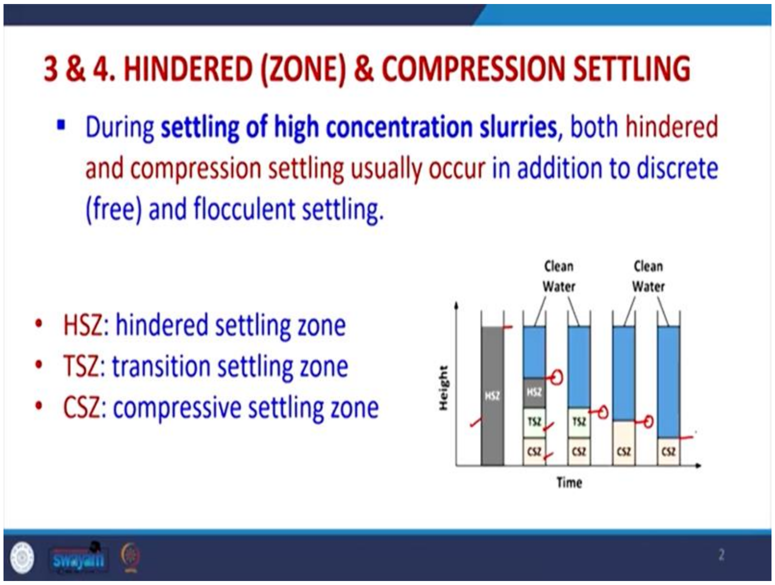

And within the high concentration slurries when the settling is happening there are different zones which are possible. So, this be these zones we have studied in detail in previous class. So, I will not be just giving an introduction that we have a hindered settling zone, we have transition settling zone and we have compressions settling zone.

And what we do is that we perform test. And we try to measure the height where there is a clear zone and where the solids are present. So, we always measure this height with respect to time so this is our interest primary interest is at the interface of the height where the clear water zone and the settling zone which may be hindered zone transition zone or compressive settling zone any of the combinations are possible, so that we cross check.

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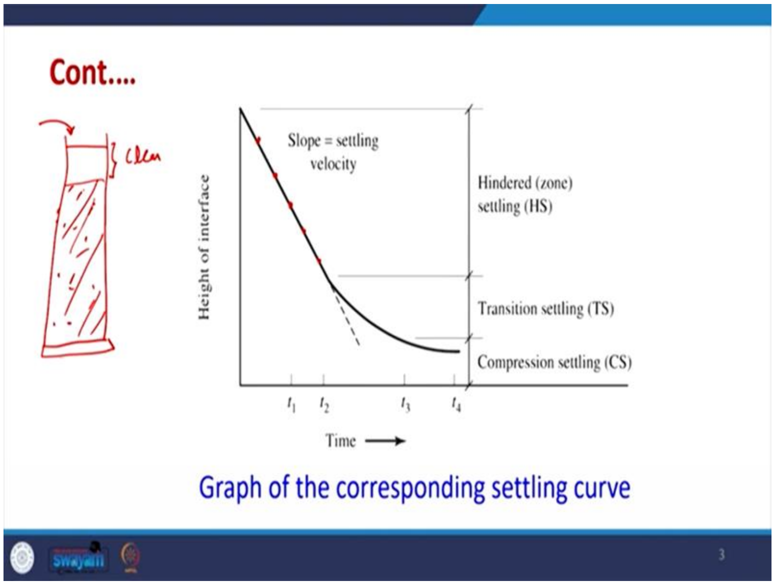

So, in the column we what we do is that we take a we take column and, in the column will be adding a water which contains high concentration slurry. And as soon as it gets mixed and we start measure the time at which we have a clear zone is there. So, this will contain lot of solid all these conditions will be there so this will be all solids will be there. But this zone will be clear zone and we measure the height of this clear zone with respect to time. So, this type of data we get with respect to time that what is the interface where the clear zone is there.

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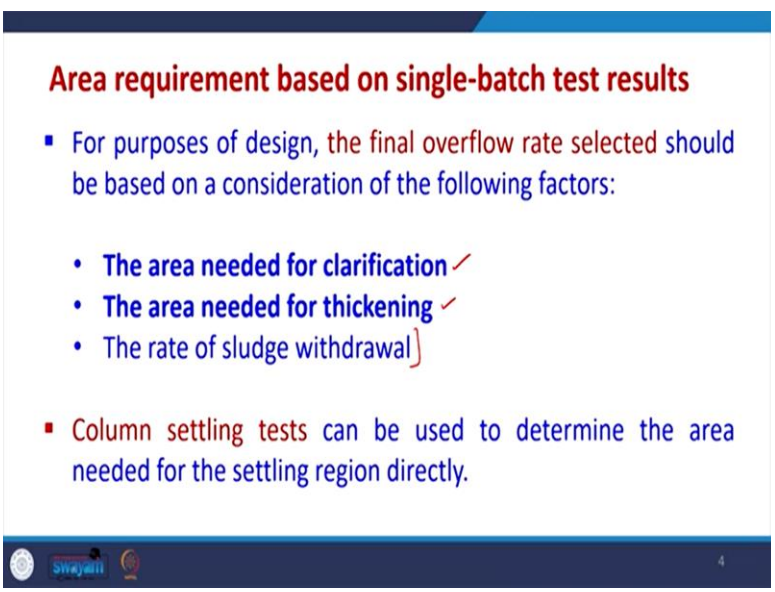

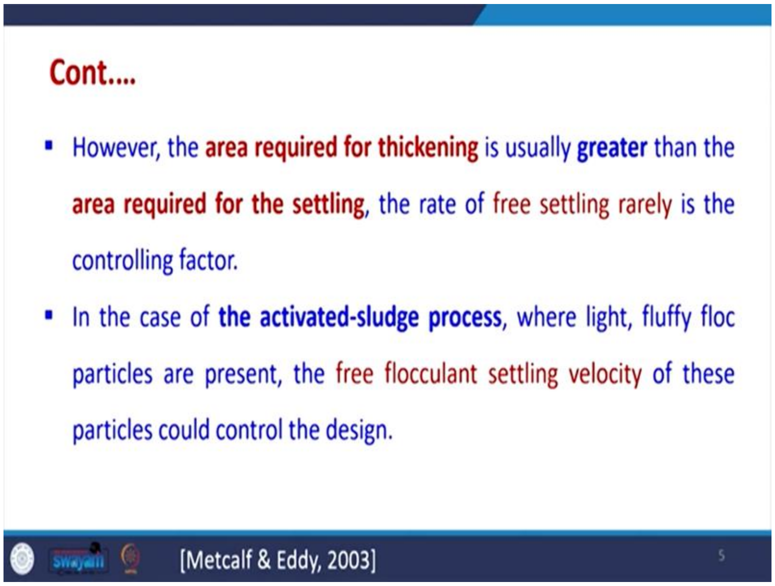

And from this data we have to find out design the overall sedimentation basis, based upon this biased test results. So, we can perform few biased test results and from that we can decide the final overflow rate and actually directly we can decide for the area which is needed for the clarification area which is needed for the thickening and rate of sludge withdrawal so that is also possible that we have to calculate that we can calculate. So, what we perform is the column settling test which from which we get the height interface height versus time data and which are further used for determining the clarification area and thickening area. So, we will try to learn these things in today's lecture.

Now, generally what will happen that area required for thickening which will be it will be much much higher than the area required for settling. So, area required for thickening will generally be higher so whichever area is higher that area will take for design of the settler so this is there. Now, the free settling velocity that that is true for discrete or flocculant sometimes that will rarely be the controlling factor for high concentration slurries. In the activated sludge process where the particles are generally light fluffy and they are activated sludge so under those condition the flocculant settling velocity sometimes may be important or flocculant settling conditions may be prevailing.

So, under those conditions the other types of behavior where free settling velocity etcetera may become important. Otherwise, the area of the thickening will generally be higher than the area of settling and that will be considered. Now, how to find out the area required for the thickening and how to find out the area required for clarification that we are going to learn right now so from the column test.

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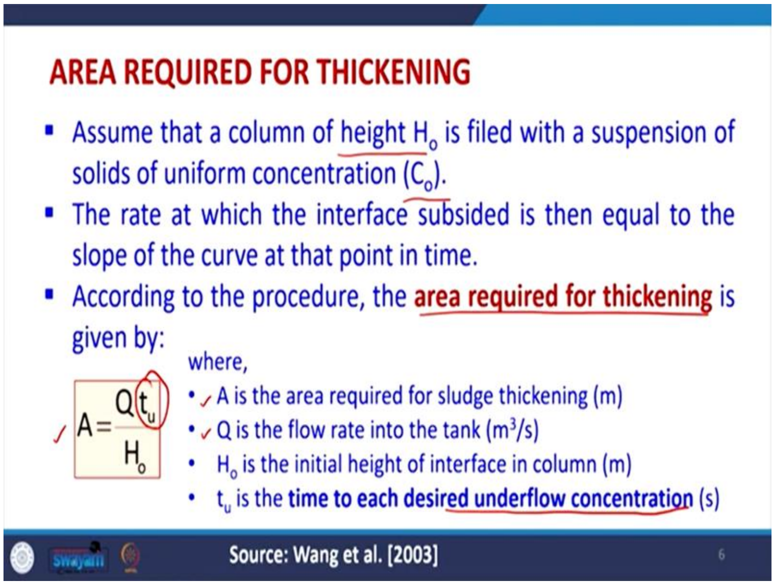

The area required for thickening is given by:

$$A = \frac{Q\, t_u}{H_o}$$

where,

- A is the area required for sludge thickening (m)
- Q is the flow rate into the tank (m^3/s)
- H_o is the initial height of interface in column (m)
- t_u is the time to each desired underflow concentration (s)

So, we are assuming that the column is having a height of H0 and it is filled with a slurry suspension like which is having a concentration of C0 so initial concentration is known. The rate at which the interface decreases or subsidies then it is equal to the slope of the curve at that point in the time so we always measure that height. Then according to the procedure, a here required for thickening is calculated by this particular equation. Now, in this equation we have to find out the area required this tu where is the time tu is the time to each desired underflow condition that we have to go.

But this tu determination is little bit tricky and that we are going to learn within this equation A is the area required for slush thickening, Q is the flow rate into the tank so that will be known this data we do not get from the bias data this is already known to us because we have to design the basin for that particular flow rate. Then H0 is the initial height of the interface in the column test and tu is the time required for desired under flow concentration. So, first this will be known to us because what is the maximum desired underflow concentration that we are going to reach that we have to decide and based upon that this tu value is calculated.

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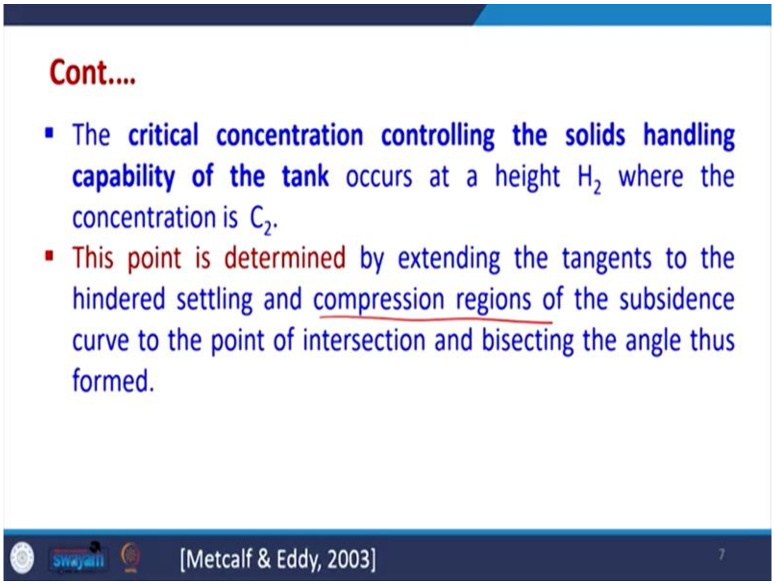

Now, going further the critical concentration controlling the solids handling in the tank that will occur at certain height H2 where the concentration is C2. So, that we have to find out and that will try to understand further. This point is determined by extending the tangents at the hindered settling condition as well as in the compression regions of the subsidence curve. So, height versus time curve to the point of intersection and by setting the angle thus form so we will try to learn it is it may not be clear right now but the procedure will learn.

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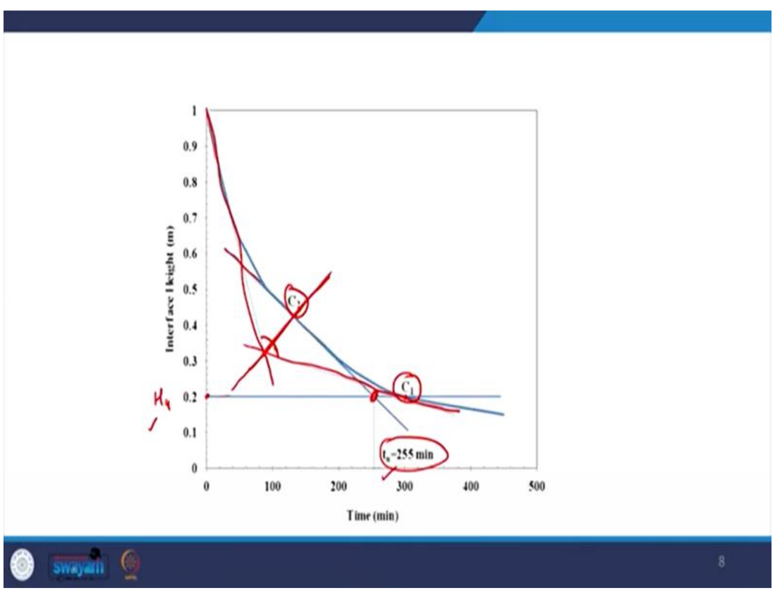

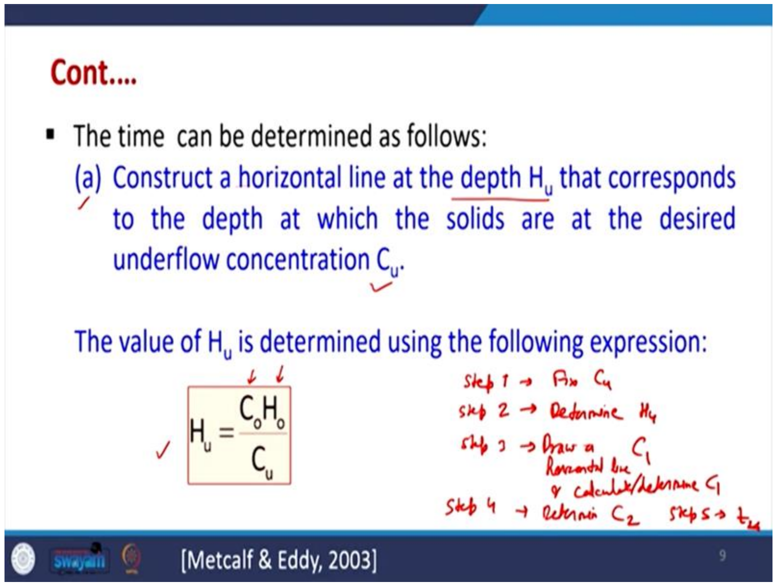

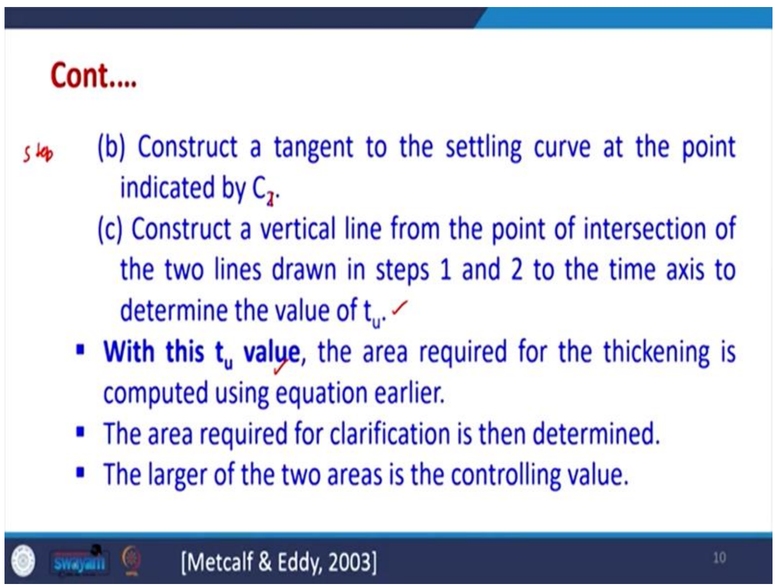

So, what we do is that we have this type of curve and first we determine this point C1, so this C1 has to be determined. And for determining C1 actually we need to know that what is the maximum interface height that we have to reach this Hu is the term generally. So, Hu can be find out what we do is that we construct a horizontal line at depth Hu. And this Hu corresponds to the depth at which the solids are at the desired under flow concentration. So, we always fix this Cu value this is the step one so we have to fix the Cu value this is the step one we can call it step one is the fix the this under flow concentration value.

Second step, step two determine Hu so we can find out determine the Hu using this equation which is given here. So, C0 initial concentration total height is already known to us and Cu the under-flow concentration already we have fixed it so Hu we can find out. So, Hu will in the curve Hu will be this point. Now, from this point this is the step third in a way that step third we draw a, construct a horizontal line at depth Hu that corresponds to the depth and it meets the actually subsidence line at point C2 this point C1.

So, we determine this point C1 at which it meets so we will have to find out determine the C1 by drawing a horizontal line so draw a horizontal line and find out C1 so horizontal line. And calculate or determine the C1 value so that this is the step so this is the third step and so we do this. Now, what we do is that we draw two curves in the step four actually we will draw two curves like we can call it a step four or something like this so a constructed tangent to the settling curve at the point indicated this before going this let us go for this.

So, what we do is that we draw a curve here then we draw a curve at the initial condition and whatever is this angle which is getting formed we bisect this angle. And so, this is we determine the C2 value so this is how we determine so step next step is little bit there are number of steps in step 4 but we have to determine the C2 value. And in the next step what we do is that we draw a tangent at C2 which meets the first line at this point and this point corresponds to tu. So, this is a little lengthy trick but this is how we find out.

So, determine the next step 5 is like determine the tu value so this this we have to determine using a number of steps so construct the tangent at the settling curve indicated by point C1. Construct a vertical line from the point of intersection of the two lines drawn in step one and two. So, we have to draw a bisection line of the point of interest whatever is the angle and that will at that point we have to draw another tangent line which meets the first line itself at tu and then we find out. So, I am repeating this overall step here we have a curve though if we can if first step is to find out H nu second step draw a curve here and which meets the settling curve at point C1, draw two tangent line one at C1 another at initial settling curve they meet at some point.

Now, we have to bisect this particular angle and this will meet the settling curve at point C2 and here again the third tangent is drawn which meets the initial horizontal line at point this and this is called tu. So, through this we can determine so and this is the procedure which is adopted to find out this t value. The area required for thickening is computed using the equation which was given here so through this we can find out the area required for thickening so this is the step. And the area required for clarification is also found out using the initial condition.

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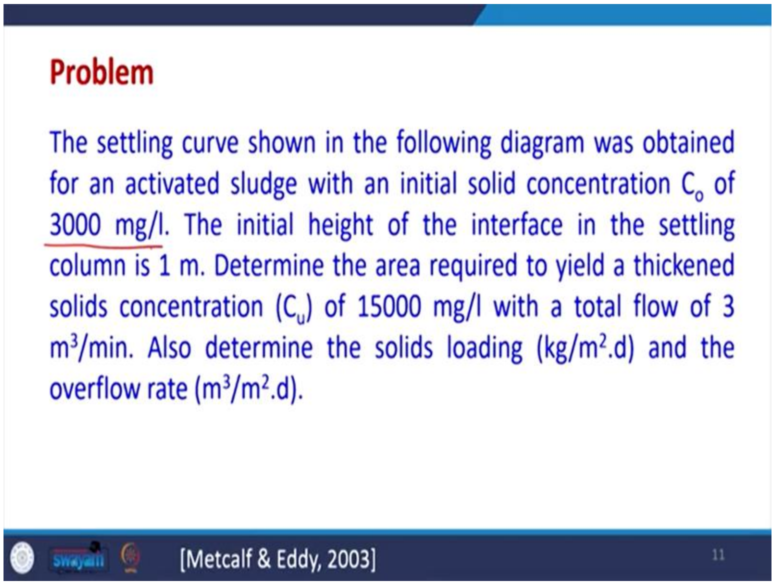

So, we will try to solve one problem and from that we will try to find out both the area required for thickening and the clarification and from here this problem will understand it more. So, a settling curve is shown in the following diagram next page which was obtained for an actuated sludge system which contained a initial solid concentration C0 of 3000 milligram per liter so this is given.

Now, in the initial height of the interface in the settling column so we have a settling column which is having a height 1-meter and we determine the what we have to do the curve is shown here this type of curve. So, this is the same as earlier but we are repeating it here so curve is shown from 1-meter height.

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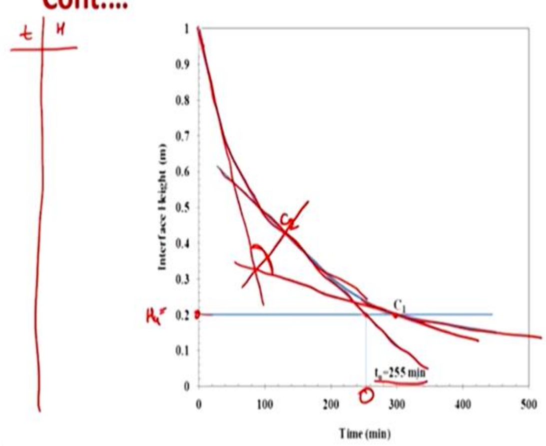


[Metcalf & Eddy, 2003]

12

Solution

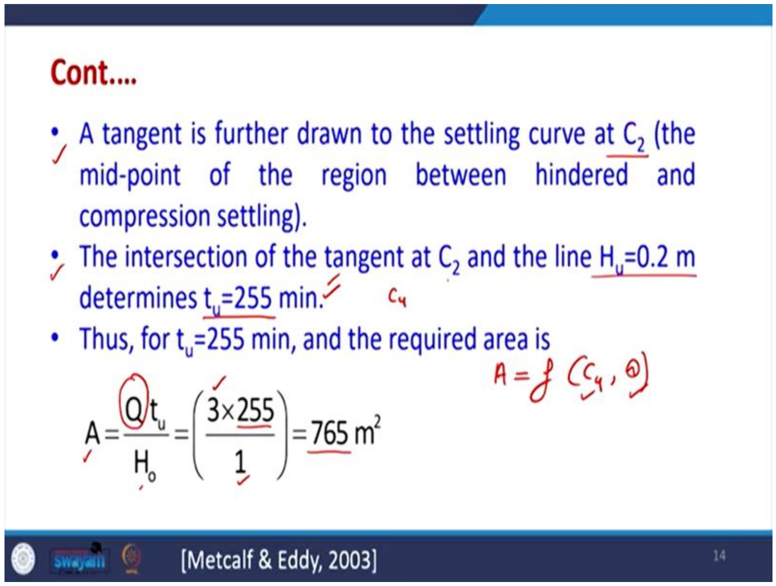
[A] Determination of the area required for thickening

$$H_u = \frac{C_o H_o}{C_u} = \frac{3000 \times 1}{15000} = 0.2 \text{ m}$$

- A horizontal line is constructed at H_u=0.2 m, which meets the settling curve at point C_1.
- Tangents are drawn to the curve at point C_1 and as well as at time t=0.
- The line bisecting the angle formed between the tangents meet the settling curve at point C_2.

[Metcalf & Eddy, 2003]

13



And it we are showing that the curve is like this the and it is going this black blue color so this curve is going like this and we actually measured with respect to time we measure the height and from this curve this data with this draw this curve so this is there. Now, from this actually we have to determine the area required to yield a thickened solid concentration of 15000 milligram per liter so ultimate concentration value is already set that we have to compress it to a condition of 15000 milligram per liter.

The total flow is we have to design the system for 3-meter cube per minute and we have to determine the solid loading and the overflow rate also so this is this is being asked for this condition. Now, let us go further and try to solve this so this is the curve which is there. So, first step is that we have to find out the Hu. So, right now we are going for finding out the thickening thickener area and for that we need to find out the Hu value.

Now, initial concentration and initial height both are given so initial concentration is 3000 milligram per liter initial height is 1 meter. And the under-flow concentration is already fixed at 15,000 milligram per liter. So, if we solve it will be finding at 0.2 meter is the ultimate height that will be there where the all the solids will remain below that. So, a horizontal what we do is that we draw a horizontal line is constructed at Hu is equal to point two which meets the settling curve at point C1 so this is there.

So, we identify h u this is equal to 0.2-meter so this point and we draw a horizontal line which meets the settling curve at point C1 so this is the step one. Now, we have to draw tangents to the curve at point C1 at time t is equal to 0. So, what we do is that we draw a curve here which is tangent to the initial settling condition and this is the curve so this is second step in a way. Now, again we draw a curve tangent line at point C1 also so draw a curve at point tangent at point C1 as well as at time t is equal to 0, so we draw the curve. At point C2 also so this is this is another tangent which is drawn.

So, now we have a angle which is there so this angle is there and we have to bisect this angle drawing a line, so the line bisecting the angle formed between the tangents meets the settling curve at point C2. So, we determine the we determine this particular line and this meets the curve at point C2 in the, this settling curve so this is the next step.

Now, the further step is to a tangent is further drawn to the settling curve at C2. And the midpoint of the reason between the hindered and compression centering. So, this point actually represents the midpoint of the hindered settling and the compression settling. And now we draw a tangent at this point and this this tangent has been drawn so you can see here a tangent has been drawn here and this tangent has been drawn.

Now, this tangent meets the initial horizontal line at this point the corresponding to which the time is known and that time is 255-minute. So, this is there this is what is written the intersection of the tangent at C2 and the line Hu is equal to 0.2-meter determine the time tu is equal to 255 minutes. So, thus we determine the point t is equal to ultimate time to be 255 minutes. And therefore, the area required for thickening can be calculated as A is equal to Q into tu divided by H0. So, H0 was the height already known t is the flow rate which is already fixed and 255 is this value and this is equal to 765-meter square.

Now, there is a trick here tick here that if we find that this is higher side or lower side what we can do is that we can in the actual system we can always divide this flow rate. So, if we may be possible we can take 1-meter cube only per minute in place of 3-meter cube per minute. So, the overall area for one thickener will get reduce so depending upon this Cu remember this tu was only dependent upon Cu so if we change the Cu value this tu also changes so that means area also changes. So, we have only two points based upon which this area can be calculated one is the this that means the area is function of the Cu value as well as the Q value.

And we these are the only two design parameters we can do because the settling curve will always be same for this water which is having a some concentration and also it depends upon the type of solid which is there which is fluffy which is higher dense low dense all those things. So, that consideration is only that height versus time curve which is already obtained from the data we have Cu which is which we can fix it and then we have Q the flow rate so this is there.

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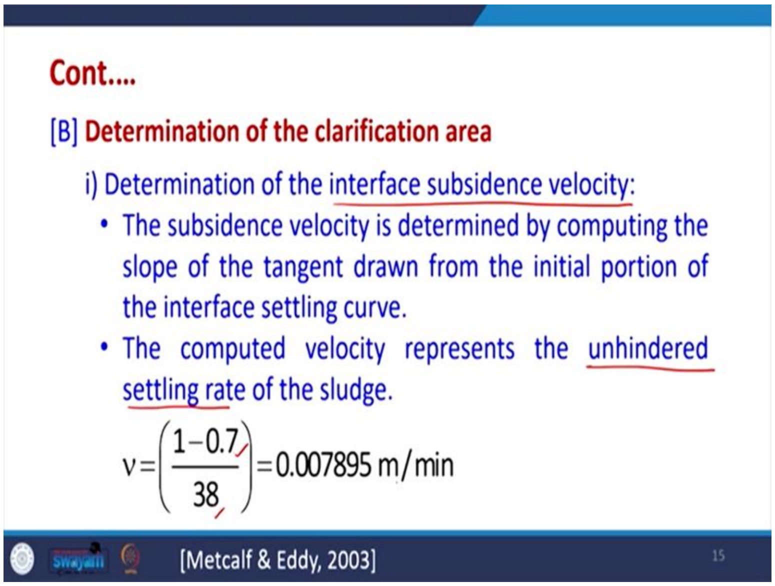

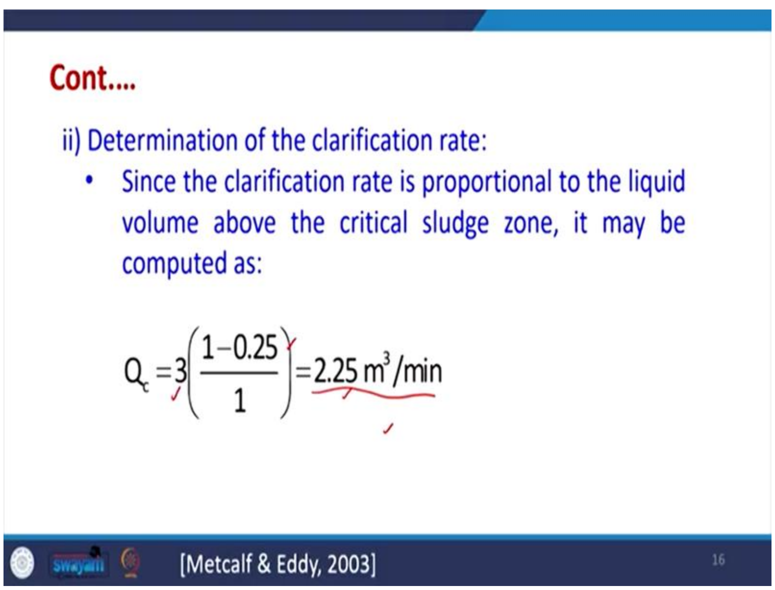

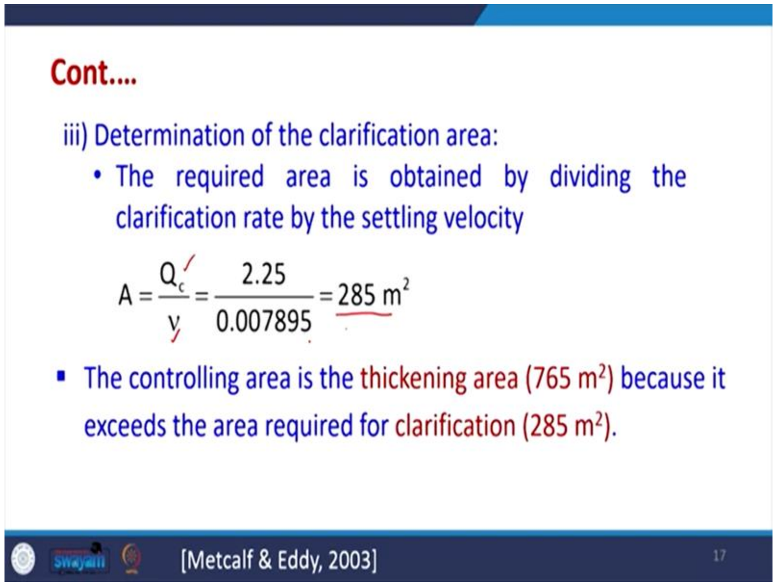

Now, we can find out the clarification area also using this approach which is given here. So, what we do is that we try to find out the interface subsistence velocity that how the interface is getting decreased. So, this subsidence velocity is determined by computing the slope of tangent drawn from the initial portion of the interface set linker. So, for time t is equal to 0 whatever is the whatever is the tangent that is drawn and from that we can find out. So, like here we have targeted up to 0.7 meter so like we can determine that up to what time it has reached.

So, we are only taking this slope so we found that up to 0.7 meter the decrease were highly linear and from here 1 minus so you can see here unhindered settling rate has been calculated using 1 minus 0.7 divided by 38 minute was the time. So, this is the velocity interface subsidence velocity we can calculate.

Now, the area of calculation is very straight forward and from this we can since the clarification rate is directly proportional to the liquid volume above the critical zone it may be computed it may be computed using this equation. So, like we what we have done is that we have only taken up to a certain height and from flow rate etcetera we can compute this QC value so this is there. And from this calculation actually 2.25-meter cube per minute we can find out this QC the flow rate has been calculated the clarification rate has been calculated.

And once the clarification rate is known we are only taking up 2.25 so clarification rate under up to this condition we can take 0.3 also so up to this is 2.25-meter cube per minute. And using the subsidence velocity as well as this clarification rate we can find out that 2.25 divided by this so area will be 285-meter square for the flow rate of 3-meter cube per minute so this clarification rate is there. Now, this area is much lower than the area of thickener so generally, whenever there is a high concentration slurry is there the thickener area will always be higher.

So, one if the thickener area is higher we always select the higher thick area and we have to design the systems based upon that area only. So, for this particular system the 765-meter square area is higher and we have to design the system based upon that only we cannot take the lower one otherwise the conditions will never be met. So, we have we can calculate the thickener area we can calculate the clarification area for generally thickener area will be higher and we have to perform the calculations on this.

So, till now what we have done is that, we have studied the settling terminal velocity in discrete settling then we went for flocculant settling then we further went for hinder settling as well as the compression settling. So, previous condition was for that, now so all the four type of settling behaviors we have studied. Now, there are different classification of sedimentation tanks. Now, we are going for further understanding the sedimentation tanks where they have to be used there may be different settling behaviors which are possible in all these zones.

So, where we commonly see the sedimentation tanks this is given here in this slide and after that we will continue with different types of settlers and other things with respect to design etcetera that how they vary there are high rate settlers etcetera. So, those things tube settler plate settlers are which are very common in now industries so we will study the details of those but before that where are the sedimentation tanks which are used.

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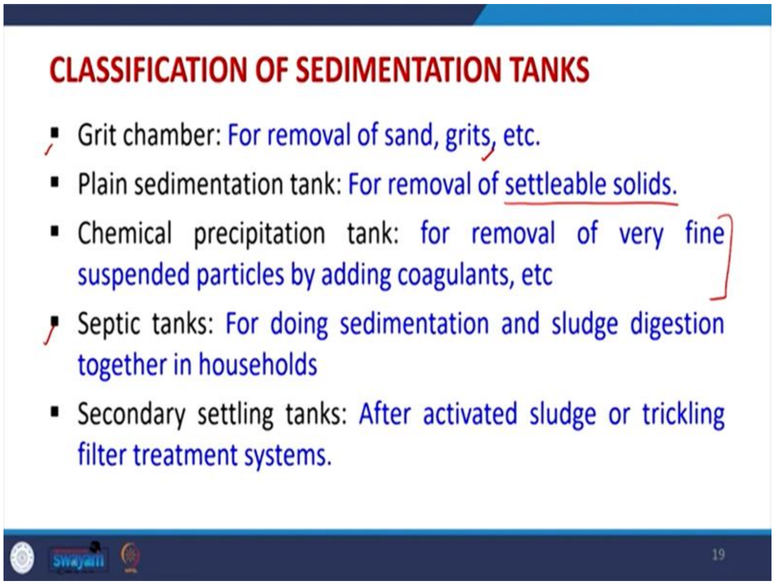

So, sedimentation tanks are used in the grid chambers for removal of sand and grits in the overall design of water and wastewater systems. So, first place where the sedimentation tank will be in the grid chamber its not very difficult to design because everything will settle down very easily. Then for plane sedimentation tank where the settleable solids have to be removed so we do not use any of the flocculant coagulants etcetera here or some may be used but generally for this the solids have enough density they can settle down or the size is bigger.

And it is possible they may have a high concentration will be there so that may be falling within the compressive or hindered settling conditions so we can design the systems using whatever we have studied just now. Now, after that chemical precipitation tank will be there so that will be removed for fine suspended particles by adding coagulants or flocculant, so under that condition flocculant settling regime may be there so we have to adopt the method that we have studied in the previous class for designing such systems. And also, it is possible that if the slurry concentration is still high we can use the hindered settling approach for the same.

Similarly, in the septic tanks that are there in our homes we have the both the sedimentation and sludge digestion both occur together so we have to take our design as per the sedimentation things that we have learn. And along with that we have to take care of that enough time is there first digestion etcetera so that is there, so here also settling occurs in the septic tank. Then in the secondary settling tanks we have not studied that much in detail because activator sludge and biological treatment we are not going to study in this subject at it as it is only for Physico Chemical Treatment.

But in the biological treatment after biological treatment there is always a secondary settling tank and that the example we have taken the previous example is of similar nature so for that also we can design the system. So, these are the different types of sedimentation tanks which are possible which may be used in different types of water treatment plant.

In some water treatment or wastewater treatment plant all of these may be there in some place only few of them may be used so it is possible to have any of these. And we can use the design ideas which are there for discrete settling, flocculant settling, hindered settling or compressive settling, so those things we can we can take further for design of such systems.

There are other tricks which have come into the picture and like in place of only upflow clarifier or simple horizontal clarifier now incline clarifier or plate clarifiers have also come. So, in those conditions what we do is that we try to see that the height that have to settle is minimum possible. So, if we can reduce the height which any solid particle has to get has to settle down so if that height is very less so it will reach the bottom of the settling zone very quickly as compared to getting out of the system.

So, overall efficiencies can be increased a lot so the systems are designed in such a manner that we have a parallel settling zones and the height is lower and we have more settling which occurs in these conditions. So, we and we will try to learn the all these things further in the next lecture onwards and will end this lecture now.

And we have studied the little bit idea regarding different types of settling zones and how we can design the system. Now, we will understand the different types of settling or sedimentation tanks further and what are the what are the settling equipment’s right now which are used in the industries. So, little bit details of those will study in the next class so thank you very much.