

Water Quality Management Practices

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Week-04

Lecture - 19

Lecture: 19 - Theory of Sedimentation and Introduction to Primary Sedimentation Tank and its Types

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Professor Gourav Dhar Bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. In this particular lecture video I will be discussing about the different type of settling and how those different type of settling parameters and the characteristics are important for us to know in order to understand and develop a system like primary sedimentation tank ok. So, let the concept that I will be covering are the introduction to the theory of sedimentation, the ideal sedimentation basin, the classification of settling, flocculent settling, the discrete particle settling or type 1 settling and hindered and compression settling. To start with the sedimentation we know that it is a process by which we can actually treat the water by removing the suspended solid from the water by the forces of gravity by the force of gravity right.

So, in general the solid that presence in the sewage it can be in different form, it can be in dissolved form, it can be colloidal form, it can be in pseudo colloidal or it can be on suspended solid form. In general the suspended solids are remain in the suspension because of the turbulence of the moving water. Nevertheless as soon as the basin is provided without the turbulence or we can reduce the turbulence or we can reduce the temperature difference or we can reduce the some other important factors this this suspended solid will definitely be settled down ok. So, this settled solid or we call it sludge can be removed easily from the bottom of the settling tank and we can be we can treat it separately.

In general 30 to 40 percent of the pollution load in terms of the biochemical oxygen demand the BOD from sewage can be reduced by primary sedimentation itself by you know this suspended organic matter which settles in the primary sedimentation tank that actually almost comes or I mean like you know in general it adds up to almost 30 to 40 percent of the total BOD load. The velocity of at which the solid settles and the bottom it

is called the settling velocity or the way that it is like in a vertical flow I would say it is this vertical velocity it is called the settling velocity. In general what are the factors which in which the settling velocity depends on specific gravity of the settling particles if the specific gravity is less it will take more time to settle is not it if the specific gravity is higher it will take less time for it to settle. Surface nature of the solid if it is if it is a having a higher viscous like you know it comes in contact with the higher viscous liquid or say like it has a certain electrical deposition on the I mean like some charge deposition on the surface and all these factors actually makes it difficult for the solid to settle or sometimes you know it is a solid to settle faster also. Density and the viscosity of the wastewater, the shape of the solid, the size of the natural all these things are actually important.

So, why does the sedimentation occur in the in the sewage treatment line? First is the grid chamber if you remember in the grid chamber along with the grid sometimes this suspended organic matter will also settled on the bottom primary sedimentation tank is there secondary sedimentation tank is there and also in the sludge thickener. So, now we will discuss about a very important physics I would say ok. So, you need to understand this first thing is the the when we design a sedimentation tank we need to understand the different type of settling characteristics of the particle different type of particle how they settle on the on the on the any sedimentation tank or any clarifier. So, we will discuss about those different type of settling classification and we will understand that how this settling settling occurs in any particular sedimentation tank or any particular clarifier ok. To start with the first one is called discrete particle settling or zone 1 or the type 1 settling.

In type 1 settling it is like you try to understand suppose you have a separate stone small stone. So, the stone if you put it in the water it it does not depend on any other parameters, but to, but on its own it directly goes in goes into the bottom into the bottom of the water body and settle there. It is like a type 1 settling means it is a discrete particle settling this particle it is not interacting with any other particles nearby or any other chemical or physical phenomena in general it is just simply because of the action of gravity it goes down in the bottom it get settled there. So, as easy as that. So, this is called the type 1 settling or the discrete particle settling ok.

So, no apparent flocculation or interaction happens between the particles in normally occurs in the grid chamber and the plane sedimentation of the of surface waters. In general the Stokes law and the Newton's law are applicable as per the settling conditions and the stable terminal settling velocity is gained by the particle under the gravity force once the particle starts the movement in a constant acceleration field which is opposed by the drag field until see. So, in general see I mean if you see the terminal velocity

which is the constant settling velocity at in at equilibrium it is nothing, but the same reason for which the water particle which drops from the sky the rain water it does it retains a certain velocity. Otherwise if the terminal velocity fundamental is not there the physics does not follow this rule the water particle will keep on accumulating with one another one with another at the end the water bubbles this water drops can be of say like couple of liter in size. I mean like it is possible like physics unless until that terminal velocity concept is there it may be like that or maybe in general there is a chance that that that particle will come with a very high velocity that it can literally penetrate the the the earth's crust ok.

So, it is possible it can be very dangerous. So, this is the same funda where this particular this terminal velocity is there. That means, the settling velocity reaches up to a certain level and then it may retains that value ok. So, in general why won it happen when;

Drag force = Total weight – Bouyancy

$$Drag\ force = \frac{C_d A \rho_w V_p^2}{2}$$

$$Total\ Weight = \frac{4\pi r^3 \gamma_s}{3}$$

$$Bouyancy = \frac{4\pi r^3 \gamma_w}{3}$$

So, where this C_D is the drag coefficient the ρ_w is the density of the fluid A is the reference area of the object facing the fluid in square meter V_p is the settling velocity of the particle r is the radius of the radius of the particle in meter and say γ_s is the unit weight of the solid particle in kg per meter cube and γ_w is the unit weight of water in kg per meter cube.

The terminal velocity of the particle for spherical surface spherical particle I would say for in when the particles in sphere in size spherical in size the v this v p square is equal to

$$v_p^2 = \frac{4g(S_s-1)d_p}{3C_d}$$

So, where this V_p is equal to nothing but the terminal velocity of particle, S_s is specific gravity of the particle, d_p is the diameter of the particle, C_d is the drag coefficient, and g is the gravity acceleration ok.

Please remember this equation this is a very important equation this to find out this terminal velocity when whenever we will be discussing about the critical velocity

settling velocity in any treatment units this equation is very important for us ok good. So, in general we know that there are different types of flow laminar flow transitional flow and the turbulent flow it can be easily differentiated by using the Reynolds number. If the Reynolds number is say like less than 1 the viscous forces are more important than the inertia force when it is between 1 to 1000 the inertia and the viscous force are equal having the equal importance and case of inertia forces are most important the Reynolds number will become more than 1000 and it actually represents the turbulent flow.

So, when we calculate the drag coefficient using the Reynolds number this C_D equal to

$$C_d = \frac{24}{N_R} \quad (3)$$

You remember in the last calculation in the last lecture we did this we use this values this C_d value and now we can easily understand like where this C_d. So, here this N_R can be easily find out by the kinematic viscosity by the diameter of the particle and then if you know the velocity of the material. So, velocity the diameter or diameter of this spherical particle divided by the kinematic viscosity you can get the Reynolds number right.

$$N_R = \frac{\rho_w \cdot v_p \cdot d_p}{\mu} = \frac{v_p d_p}{\nu} \quad (4)$$

So, during the settling in the laminar flow you remember this equation number 3 right in case of laminar flow where the force of viscosity is predominant and they are only the first term in this equation (3) $\frac{24}{N_R}$ is important. So, that means, in case of laminar region is the first one in the if you see the left top left the first one laminar flow in case of laminar flow this C_d value can be easily find out by $\frac{24}{N_R}$ that is it the rest of the rest 2 expressions are is to I mean like the terms are not needed ok.

In case of turbulent region where the inertia force is dominant in the last one N_R is more than 1000 what happened in that case the first 2 terms in equation number 3 is not significant. So, it reduced to its maximum values most somewhere around 0.34 to 0.40. So, C_d value becomes very less it is around 0.34 it is a it is comes down to very minimum ok. So, this is called the this happens in case of turbulent flow what happened in case of transitional flow which is when it is in between laminar and the turbulent flow. In case of laminar in between this laminar and turbulent flow we it follows this equation C_d equal to

$$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34 \quad 0.34 \text{ ok.}$$

So, in case of laminar flow as we discussed it is only 24 by N_R and turbulent flow it is only around 0.

34 to 0.4 and for transitional flow it follows this equation and by using the stokes formula you can easily for terminal settling velocity under laminar flow you can easily calculate V_s equal to

$$v_s = \frac{g(\rho_s - \rho_w)d_p^2}{18\mu}$$

From here and the transition flow also it will follow the same equation. So, now what are the assumptions we do in case of ideal sedimentation basin design first we need to understand this you see this you know the what is the difference how it looks like laminar flow and the turbulent flows and all. So, here in general in case of ideal sedimentation basin it type 1 settling of particle occurs the quiz the question condition prevails in the settling zone and the even distribution of the flow occurs throughout the cross section of the settling chamber the settling zone you see it is like a continuous you see that there is no turbulence. So, there the uniform distribution of particle is present throughout the depth no scouring of the particles occurs after the settlement also the wastewater containing the uniformly distributed sediments enter the settling tank with a uniform velocity capital V the discharge should be uniform Q the dimension of the tank are l into say breadth into b into settling height is capital H. So, for the velocity flow velocity of capital V can be easily calculated as per the equation 6 that is equal to

$$V = \frac{Q}{A_c} \quad (6)$$

A c is nothing, but the cross sectional area of the tank which is nothing, but the breadth into height.

So, that is the cross sectional area. So, Q which is the flow rate divided by the area you will get the velocity here right.

$$\text{So, } V = \frac{Q}{A_c} \quad \text{here ok.}$$

So, the settling velocity can also be found with this $v_s = \frac{H}{t_0}$

H is the settling depth divided by t_0 is the detention time of the wastewater in the settling basin that is also possible. So, this is this is the settling velocity settling velocity suppose it reaches it from the top your wastewater enters and it goes up to the bottom that is particular solid particle that for particular solid particle to reach to the bottom how much distance it will cover H the settling depth capital H and how much time it will take to settle down say like t_0 .

So, $\frac{H}{t_0}$ you will get the settling velocity meter per second in meter per second you understand. So, that is how also you can find out the settling velocity. In case of ideal sedimentation basin you see it will obviously, follow this equation see it will go like this. So, for ideal basin no sediment will cross no solid particle will cross this line it will obviously, settle down somewhere here ok. So, if it should the V s value is the here the V s is actually should be finalized we need to we need to we will find out that what is this V s and what is this V s dash ok.

So, in which case in general our target is to somehow get the sediment settle using maximum following this zone. So, this zone is the one where actually most of the sedimentation occurs I mean like theoretically our target will be like this ok. So, from this trajectory of this figure 2 you can see the constant horizontal flow velocity V and the different settling velocities are there for different for wastewater entering from different depth ok. And so, in general the V s more than equal to V s if it is the V capital V is

higher than the V_s the settling velocity the what will happen the particles will settle down and completely removed from the wastewater ok. This small v is nothing, but this one.

So, in general say the I mean like the velocity in the in general the say velocity at which it is settling on the bottom if it is more than settling velocity that mean that means, it will definitely settle on the bottom ok. So, in general this quantity of the settling velocity also can be called surface overflow rate this or the surface loading rate it has a unit of meter cube per meter square per hour or per day and how we can find out it is very easy we just need to know the

$$t_0 = \frac{L.B.H}{Q}$$

So, from there you can get the total detention time also

$t_0 = \frac{v_s}{H} = \frac{v'_s}{h}$. Try to understand this fact this t_0 detention time right V_s what is V_s here is the settling velocity settling velocity is the V_s and h is the height.

So, settling velocity divided by height if you I mean like if you have settling velocity divided by height is equal to from there also you can find out the settling velocity V_s dash equal divided by h if those are all obviously, the same ok. So, I think here the equation should be T_0 T_0 is in general it is in say it is in second.

So,
$$v_s = \frac{H}{\frac{L.B.H}{Q}} = \frac{Q}{L.B} = \frac{Q}{A_s}$$
 you understand.

So, from there you we can easily get. So, l is the length of the settling zone in meter and b is the width of the tank and h is the height of the settling zone and A_s is the surface area surface area of the tank and p is the particle particle limit. So, in case of p value you can easily find out h by T_0 T_0 is equal to obviously, capital H by T_0 h is any particular height here divided by T_0 which will be obviously, if you divided with capital H by T_0 you will get the particles the amount of particles that it removes. So, which can also be done by small h by capital H . So, for estimating the fraction removal on the particles entering to the different heights can be easily calculated.

In case of ideal basin another thing is like we normally go because of large variation of particle size are there we batch settling test we normally perform. Here if you see this is the p_0 this is the maximum amount of particle that would be settle there and then the rest of the portion will escape. So, here if you see the settling the fraction removed in the fraction of solid that is removed is $1 - p_0$ plus 1 by v_1 by v_s integration of 0 to p_0 v into $d p$. So, here if you see the fraction of particles first when 1 is to p_0 $1 - p_0$ is nothing, but fraction of particles with the settling velocity v more than v_s . That means, that much of this the v is more than v_s what will happen obviously, all the things will settle is not it plus the portion some fraction of the particles will also stay if even if the v is less than v_s right v is less than v_s means the velocity is the velocity is less than the settling velocity.

So, that means, it may take more time if the this velocity this small v is less than

settling velocity what will happen if it is less than settling velocity. That means, it will take more time to reach some there is a chance some of them will actually escape from the system. So, it will not reach to the I mean it will escape to the outlet because it will not reach to the bottom you understand. So, that is that is the thing. So, overall this efficiency of settling it depends on different factors the wind effect the energy dissipation at the inland because there may be some eddy current that may generate the settling tank volume the upward draw at the outlet the sludge removal equipment turbulence the temperature difference the difference in density short circuiting.

So, short circuiting was like you know somehow it is connected with another like in the follow up treatment units and also it. So, there are different efforts at which actually settling tank design actually matters ok. So, one of the majors are tabulated here I mean like the mentioned here. Another type of settling that we will talk about it is called the flocculent settling. So, you understand about the zone settling zone 1 settling or the type 1 settling right.

So, in the discrete particle settling now we will talk about the flocculent settling. So, how what is flocculent settling in case of flocculent settling what is happening it normally occurs in the dilute suspension region in the dilute suspensions what is happening certain particles tend to coalesce and they form the aggregates and call the we call it floc. So, because of this floc through this flocculation process it increases the particle size and slowly it enables the faster settling in the waste water. Sometimes we purposefully introduce some kind of chemical which actually enhances this floc formation. So, if the floc formation will be more it will settle down in a faster rate ok.

So, normally it occurs in the primary settling tank and also the upper part of the secondary settling tank. The mechanism is majorly the difference in settling velocity causes the faster settling particle to overtake and coalesce with the slower settling once ok. And this velocity gradient of this waste water lead to the particles of high velocity region to overtake those in the adjacent path with the slower velocity and they will take each other and they will slowly go down. There are different test by which actually we can check we can actually identify we can analyze the flocculent settling phenomena it is a batch settling test typically required to evaluate the settling characteristics of flocculent settling particles. Settling column test we conducted to evaluate the applicable residence time and the surface overflow rate for designing the sedimentation tank.

In this settling column is normally constructed with the same height as it is proposed in the settling tank with a sampling port provided at equal interval. So, it is more like suppose your actual settling tank you want to design it for say 5 meter say like 2.5 meter or 3 meter. So, for actual 3 meter you what you design you design a small one small diameter cylinder. So, this cylinder should also have a same height same height of the settling tank suppose 2.5 meter to 3 meter. Now, you put every after 0.5 meter you make a hole and you collect some sampling port. This is called settling column test in settling column test this sampling ports are there in general the internal diameter of the settling column should be at least 14 centimeter to minimize the wall effect to adsorbed in the wall. And the precautions what needs to be taken the temperature should be maintained

uniform to avoid any convection current and uniform distribution of solids should be there to maintain throughout the depth of the column at the beginning of the test. What are the assumptions the duration of the test is assumed to be equivalent to the settling time proposed for the time and the samples are withdrawn from the ports and examined for the suspended solid concentration.

What are the factors that influence the flocculations here first is the particle size range the tank depth the contact time the particle concentration the velocity gradient overflow rate and the surface properties ok. So, if you if you see this flocculation parameter this is suppose the graph that we have drawn. So, suppose we have the this 0 to h 5 this is say like the height total depth you say like 5 meter. So, for this 5 meter it is divided into say 1 meter each. So, from there you take you have the port from the port you collect the sample after every say half an hour 60 minute 90 minute 120 minute and 150 minute.

So, every other time whenever you are collecting the samples you will put the you will take the sample and you will you will find out you just simply draw this graph by interpolating and extrapolating I mean like the connect the different dots with the different values that you have found out and you prepare this nice graph. If this graph if you see this sampling ports and this settling column test with this graph is actually what is this representing this 80 percent line. That means, this line representing that it is a it is called isoremoval line means this line is representing the same amount of removal over a certain period of time for different height. That means, suppose you have let us take 60 percent line 60 percent line if I take it is this line is actually somehow see in this particular line when it is intersecting the 30 minute line. That means, that after 30 minutes in this particular zone on above the water is removed there was solid 60 percent of the remove 60 percent of the solid is removed on the top of it ok.

So, this 60 percent removal if you see around 40 60 minute 60 minute more than at this particular height. So, suppose if it is like total 5 meter. So, it is 1 2 3 3.5 meter height the 60 percent of the water is actually removed from there on the on the top definitely it will be more because water becoming more clearer ok. So, this 60 percent line actually slowly shows that suppose in this particular line after 120 minute say around 0.5 meter from the bottom that part is actually having 60 percent removal. So, that means, it will take more time on the later size right like you know in I mean like compute have a complete removal like you know to take place and I would say like the height the more you reduces the height it will take like you know what will happen at the end the final removal maximum amount of removal will take place on the surface much easily then in the bottom ok. So, thus then in the bottom that means, the it is become 60 percent of the solid that means, the 60 percent this means means like all this means after 120 minutes all this 4.5 meter height is normally less than 60 percent solid is there that means, the what almost it is clear it is getting clear.

So, that is that is how it is actually it looks like. So, this from this graph and using this equation this fraction particle removed in can be easily estimated ok. So, we will do it we do one numerical. So, that you please write it down this equation this is sum of H_1 to N in bracket capital this $\Delta H/N$ $\Delta H/N$ is nothing, but this height suppose this say

let us take this 80 percent line. So, this is called the ΔH this portion is the ΔH and 2 total capital H is the total height capital H is the total height say which is 5 meter and ΔH will be say 1.6 meter this much this is called ΔH in this particular case.

So, in this particular case the removal efficiency also you can get R_N is the represents the removal total suspended solid removal in percentage. So, R_N will be 80 percent and R_N plus will be say like 100 percent. So, if you take this one. So, ΔH will be this portion 70 percent to 80 percent. So, now, for this equation how for this particular line say like what this 120 our 120 minute line 70 percent to 80 percent this graph this portion how this portion will be represented by ΔH and by H is capital H is 5 for this particular case just giving I am giving you one any random example.

And now this portion now what will be the R_N R_N will be 70 plus R_N plus what is 80 percent is divided by 2. So, 70 plus 80 divided by 2 multiplied by ΔH say this much is say like almost 1 meter multiplied by 1 divided by capital H means total 5. So, that value will actually represent the total suspended solid removed in percentage ok. So, that is how we take we will do a one numerical. So, it will be more easier for you to you know understand ok.

So, in general when we apply this laboratory experiment. So, we need to understand this values in clearer manner ok. So, in general this propellant settling the different eddy current what are the factors that affect first is the eddy current. Eddy current means the moment wastewater enters it makes some hindrance and all it will make it make a like a this kind of flow it is like you know it will make a like a eddy flow you know you search for it you know it is like water when drops from in the stair it makes this eddy current ok. So, this eddy current it will go back to the system. So, this eddy current flows can actually formed by the inertia of the incoming fluid the wind induced turbulence on the water surface if it is like very huge and there is a huge wind flowing on the surface on the top because of the wind the surface will also create some wave.

Thermal convection current because of the very hot summer changes in the temperature and create the this they create this there is some problem in the propellant settling cold and warm water causing the formation of density current and also thermal stratification in hot climate as I also already discussed. So, in general this correlation between the removal efficiency r and the nominal detention time t can be easily represented by capital R equal to t minus t divided by a plus b into t a and b are the empirical constant. So, there one very important things please try to remember the factor of 0.65 to 0.85 has to be applied when you design the settling velocity. Suppose you will design this I mean like you will find out the settling velocity you will estimate the settling velocity in a column test, but in actual case it should be it should be not more than 0.85 then the actual number. Same time suppose you will find out the detention time of your reactor should be say 1 hour, but you have to multiply when you do the this settling test column test I mean like in your column test. In your column test if you find out that your detention time should be 1 hour in actual case actual design you have to do it at least 1.25 to 1.5 times more. So, suppose if it is like 1 hour in case of column test you will you are you find out that your actual detention time is 1 hour actual case you have to make it

at least 1.5 hour 1.25 to 1.5 hour in real life situation ok. So, these two factors are very important you have to write it down 0.65 to 0.85 for settling velocity and 1.25 to 1.5 for the multiplication factor is there for detention time. Let us do this numerical as you remember we so, this graph is given to you this graph you can easily find out by I mean like you can easily draw it by yourself when you have a settling column of say like what is the height given in the in this example 2.5 meter ok. So, 2.5 meter is the total height. So, total height is 2.5 meter each one is having us gap of 0.5 meter and there is a port 1 or port is there suppose there is a say there is say like 1 rectangular I mean I say 1 cylindrical column of 0.25 2.5 meter in height and every 0.5 meter you have a port. Then you calculate then you introduce the waste water in wait for say like 150 minute and you get this line this in this particular graph you can easily draw. Now you are asked that sample are collected in the different 30 minutes from the resident of the ice remover and. So, now, determine the overall removal of solid after 1 hour of settling after 1 hour of settling means 60 minute you have to find out the overall removal of solid total removal of solid how you can find out the total removal of solid you remember that equation you can easily find out using those this equation $\frac{\Delta h_1}{h_5} \times \frac{(R_1 + R_2)}{2}$ this is the this value this $\frac{\Delta h_1}{h_5}$ value is what how we can find out you can easily find out from if it is like a put it in the graph paper you can easily see. So, if it is like total is 0.5 it will be somewhere around say how much it is in this particular case.

So, 0.5 it is 0.313. So, this value is 0.313 in in this particular case. So, we need to know this value we need to know h_5 h_5 is the whole whole total. So, all total h_5 is how much 2.5. So, now, plus R_1 plus R_2 R_1 is how much here 90 R_1 is sorry R_1 is here 100 percent removal in the top it is considered the 100 percent removal and this line is considering the 90 percent removal.

$$\frac{\Delta h_1}{h_5} \times \frac{(R_1 + R_2)}{2} = 0.313(100 + 90)/(2.5 \times 2) = 11.894\%$$

So, from there you can get the removal percentage from this portion. Now, what happened to the this portion this portion $\frac{\Delta h_2}{h_5}$ is how much say from the graph paper you can easily find out it will be somewhere around 0.156.

$$\frac{\Delta h_2}{h_5} \times \frac{(R_2 + R_3)}{2} = 0.156(90 + 80)/(2.5 \times 2) = 5.304\%$$

So, total is 0.5. So, it is somewhere around 0.156 then point again h_5 h_5 is 0.5 sorry 2.5 and we also know what is the R_1 here R_2 here R_2 is 90 R_3 is 80. So, 90 plus 80 divided by 2. So, likewise if you keep on doing it for all these different values all these different zone.

$$\frac{\Delta h_3}{h_5} \times \frac{(R_3 + R_4)}{2} = 0.281(80 + 70)/(2.5 \times 2) = 8.430\%$$

$$\frac{\Delta h_4}{h_5} \times \frac{(R_4 + R_5)}{2} = 0.531(70 + 60)/(2.5 \times 2) = 13.806\%$$

$$\frac{\Delta h_5}{h_5} \times \frac{(R_5 + R_6)}{2} = 1.219(60 + 50)/(2.5 \times 2) = 26.818\%$$

So, you will you will if you add it you will get the total percentage removal. So, from

first zone you will see the removal is 11.89 percentage then 5.34 then 8.43 then 13.8 then here is 26.8. So, that means, total removal is 66 percentage. So, after 1 hour you can reach 66 percentage of suspended solid removal. So, this 66 percentage of suspended solid removal in actual. So, in actual case in order to reach 66 percent how much time you will require you remember in I told you just in the last slide that in column test if it requires 1 hour in actual field scale it can be up to 1.25 to 1.5 hour ok. So, in real life in when you actually design the settling tank in that settling tank to reach this 66.25 percentage removal you may have need almost 1.5 hour of retention time very good. So, now, let us talk about the another two types of settling the one is called the hindered settling or the type 3 settling another one is the compression settling. In case of hindered settling it is a intermediate when it occurs when an intermediate concentration of the particles are present and which actually add some adhesion or the cohesion forces between them and because of that it disrupts the settling of adjoining particles it is called the hindered settling it is hindering the settling you can understand from the name and it is also called the zone settling ok.

It is like a zone settling it is settled line as a zone then there is a compression settling or the type 4 settling. In case of compression settling such that the particles are touching each other and further downward movement is only possible because of the compression of the particle in the binet because it is already reaches on almost the almost free stages and then after then it is only possible for further settling if the if the layer on the bottom of it will compress then only the upper layer will settle further. So, it is called the compression settling or type 4 settling it occurs in the slice sludge thickener the lower parts of the secondary sedimentation time ok. In case of when we try to find out the analyze the hindered settling when high concentration of the suspended solid is present it both hindered settling and compression settling can be experienced ok. If you see this particular graph in this one column is there in this column you introduce the waste water it actually you can see this different type of settling zone clearly.

First one is discrete particle settling in the first zone where the this particles will settle like a individual particle. Then flocculant settling equals you can witness then the hindered zone settling and then at the end on the bottom you will see the compressed zone settling on the compressed region. So, in and on the top there will be the clear water. So, this kind of column test will give you a clear pictures of how it will look like if you have a transparent glass or the transparent I mean like the plastic cylinder you made it. So, from there you can easily you can use the PVC pipes and also I mean like or acrylonitrile pipes and all.

So, to make it like you know transparent anyway. So, in this kind of settling you will see this kind of if you do this kind of single batch settling test results you will see this capital H is actually in this case like the maximum height. So, from there to the concentration to if you see the it will reach a different zone this is the flocculant settling zone then there is a hindered settling then it comes to the compression settling ok. So, it reaches a different time and because of that also you can see. So, in general it looks like a pyramid the high concentration at high concentration of suspended solid in the top basically and the flocculant occurs at the top and hindered and compression occurs on the bottom ok. So,

with time with the depth you can see the slowly the settling illustration this is the settling parameters you can see in the in the very typical characteristics of it.

So, this zone represents this one this zone represent this one and this is the secondary zone this I mean like this part of it the discrete and the flocculant part ok. Let us do one numerical to make it more like memorable for you. So, what we are doing suppose in this particular numerical you are asked that in a settling cylinder of 2 meter height. So, total H_0 is how much 2 meter 2 meter of height in this figure 8 it obtain the initial mixed liquor suspended solid concentration of 4000 milligram per liter. So, C_0 is given determine the area to yield a thickened sludge concentration C_u is 18 gram per liter.

So, this C_u is 18000 milligram per liter this is 4 milligram 4 gram per liter this is 18 gram per liter ok. So, you try to make it in a same unit. So, it will be easier for you can make it 18000 milligram per liter ok and inflow is 100 meter cube per day q is also given in the sedimentation tank. So, now, you know the C_0 value you also know the height 2 ok. So, how you can find out the C_H this value I mean like this height this height you can easily find out if you know the C_u in general if it is there in the same column right in the same column the height multiplied by the solid concentration initial solid concentration is 4000 milligram per liter.

So, then suppose you when you introduce it it is in this uniformly present in the column. So, in this uniformly present in the column. So, the height requires for 4000 milligram per liter is say 2 meter ok. So, what will what will be the height that it requires for having a final the sludge thickened sludge concentration of 18 gram per liter it can be easily done by a simply unitary method it is like you know H_0 into say $H C_0$ into H_u equal to C_u

So, H_u can be easily find out C_0 into H_0 equal to 4000 into 2 divided by 18000 0.44 meter. So, that means, at 0.44 meter you will have the thickened sludge I mean like the that you can expect after certain time. So, that also will be anyway. So, we can draw a horizontal line from this 0.44 to this compression settling zone say like this will be 18 milli 18 gram per liter. So, if you draw this line and from the C_2 C_2 is the zone at the settling curve and from the C_2 curve if you have a if you draw a tangent. So, this tangent at it will interact it will intersect this particular line at a certain at certain point right this this at this particular junction if you collect connect that draw another line parallel to the y axis it will reach the time axis or the x axis or the abscissa axis at certain value. So, this value we found out at 170 minute. So, that means, after 170 minute you can have the compress settling at 0.44 meter height where the final sludge volume will be around concentration will be 18 gram per liter. So, from there you know the this value this a this T_H value T_u value also we know now you can easily find out the area that it requires because area is nothing, but the Q into T_u by $h Q$ is what the flow rate ok. So, if we know the flow rate which is 1000 it is given 1000 meter cube per day. So, make it to the second make it to the minute at least. So, 1000 divided by 24 into 60. So, now, we are making it into meter cube per minute multiplied by 170 is the minute as we can find out from here 170 minute divided by 2 meter is the actual height ok.

So, from there you can easily find out meter cube per minute into minute divided by meter. So, it will become meter square. So, 59.03 meter square is actually the area that is required for the clarification. So, this is the clarification area that it requires in real scale ok.

So, from here you can easily find out the real scale clarification area that it requires. Also now we can easily find out the subsidence velocity subsidence velocity here we know that from 80 to say to in order to reach to 72.5 minute we can easily find out this is the flocculent settling zone. If we know the flocculent settling zone we can easily find out the 0.9 is the height and also 72.5 minute is the time that it requires for flocculent settling like I mean like to in order to reduce to the flocculent I mean I need to go ahead with the flocculent settling phenomena to done.

So, in this particular zone what is happening flocculent as well as in the discrete settling zone. So, there this subsidence velocity can be easily calculated by 2 minus 0.9 divided by 72.5. So, 2 minus 2 is the maximum height and 0.9 is the rest over. So, 2 minus 0.9 divided by 72.5 is the minute. So, from there you can easily calculate the multiply by 60 you can calculate the velocity as 0.91 meter per hour. So, we can easily find out from this the overflow rate overflow rate is 1000 if you see this particular value again particularly again.

So, this is the total change in here 2 minus 0.44 that is the total area that it requires in general if you draw if you actually see one cylinder here this is the total area that is a total volume that is available and. So, this in this volume only what is happening the overflow rate is happening. So, 1000 meter cube divided by what is that area available 2 minus 0.44 by 2 that much percentage is available this much percentage is available say if we have a cylinder.

So, you can calculate it that volume is around 780 meter cube per day. So, this portion is actually representing the overflow rate. So, if you consider this value and we can calculate the subsidence velocity we can get the area of 35.71 meter for flocculent settling zone. So, that means, that area is not the controlling area controlling area is actually in the area required for the thickening area which is the 59.03 which is higher. So, our design should be of 59.03 not the 35.71 you understand. So, this 59.03 if we introduce we can easily find out the solid settling rate 100 meter cube per day flow 4000 gram per milligram per liter or gram per meter cube is the if you remember the initial the concentration that is that is given. So, from there you can easily calculate the and the area is given as thickening area the area required for the clarification 59.03 meter cube meter square. So, from this equation expression we can easily get the solid retention time 60 loading rate 67.76 kg per meter square per day and hydraulic loading rate also we can get it to total area for the overflow rate is I mean like overflow rate is 780 meter cube per day divided by the area the area for thickening which is 59 meter square.

So, from there hydraulic loading rate will be 13.21 meter cube per meter square per day please remember this steps when you are going to design it. So, good. So, what we have discussed in this lecture till now it is we did not discuss about the different type of

settling. So, we have a very good idea now what is type 1 settling what is type 2 settling type 3 and type 4 and how we can actually calculate those settling values and all. So, this is a very important for you to understand in order to design a primary sedimentation tank which will be doing in the coming week ok.

So, this is the reference sequencing and thank you so much we will see in the next lecture video with the further discussion about the primary sedimentation tank design and all ok. Thank you so much. .