Water and Wastewater Engineering
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Sedimentation
Lecture # 8

Last class we were discussing about what's the need of water treatment and we have also seen how to select the water treatment processes. We discussed how the treatment unit or treatment operations vary depending upon the source of water. Actually we have to improve the quality of water. So, if the source or whatever water comes to the treatment plant or whatever raw water is available to us is not of good quality then naturally the extent of treatment required is very high. Moreover, if you take the water from the ground or underground then we have to give some extra treatment and if you take the water source or surface water then it requires a different treatment, at least the initial treatments.

Thus, we have seen about how to go for that treatment. Especially we have discussed about the aeration which is essential for ground water because in the ground the oxygen availability is limited so there are chances of it having odorous gases and elements which is in the reduced form. So to remove these things we have we have to go for aeration. We have also discussed about the different types of aeration units available and how to design them and what are the design parameters. Then we were discussing about solids separation. In water treatment itself we come across different types of solids; suspended solids, colloidal solids, dissolved solids which we have discussed earlier and when these solids are in liquid or in solution the suspension can be of various types. Sometimes the suspension is stable and other times it is unstable. This stability or unstability is discussed or expressed in terms of the colloidal or the solid stability.

For example, if you take a colloidal solution the colloids are so stable because of the Brownian motion and the surface characteristics so it is very difficult to remove the colloidal particle from the suspension by only physical force. But if you take a solution or a suspension which is having suspended particle or particle with high density and large size then it is very easy to remove them by physical force I mean by gravity.

Today we will be concentrating on the removal of particles which is of higher size which can be removed easily by sedimentation or by settling and this sedimentation is a unit operation because we are making use of the gravity force and gravity is the driving force here.

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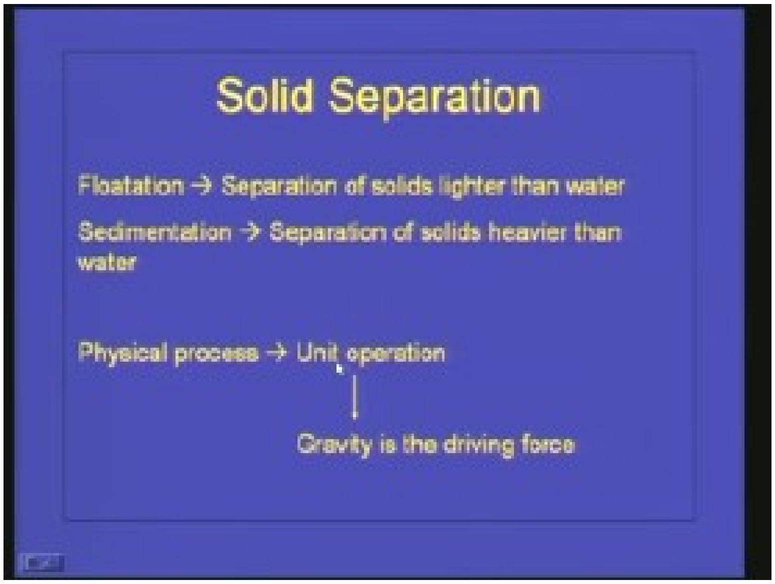

This is a physical force and we can call it as unit operations. Another treatment commonly used for solid separation is floatation. Floatation means the separation of solids which is lighter than water. But in water treatment most of the solids whatever we deal with is always denser than water so most of the time we won’t go for this floatation but we always go for sedimentation.

As I have already discussed the suspended solution can be unstable with respect to the suspension and can be stable with respect to the suspension. So if it is a suspended solution then it is unstable because the size of the particles are high and the density is relatively high so it will be easily settling. But when you come to the colloidal and dissolved solution they are stable.

If you want to treat this stable suspensions or if you want to remove the solids from the stable suspensions first we have to make the solids unstable or make the suspension unstable with respect to the solids then we have to remove the suspension or we have to remove the solids by settling.

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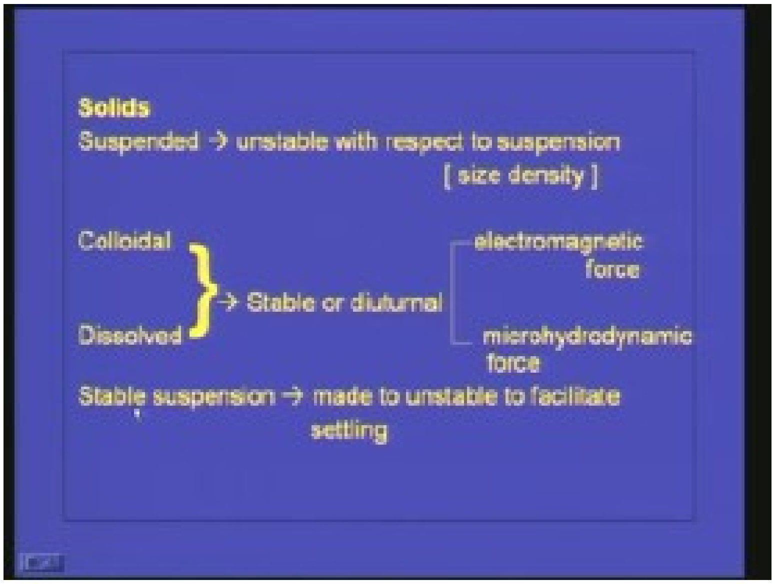

Coming to the sedimentation first we will discuss what are the different types of particles. It is very very important when we go for the design of sedimentation systems. The particles can be classified basically into two categories; one is discrete particle and another one is flocculent particle.

Discrete particle is the one whose size, shape, and specific gravity do not change with respect to time. For example, if you have a suspension of sand or silt and if you allow it to settle in a quiescent condition then what happens is each individual particles will be settling down and if you analyze the size or shape or specific gravity of that particles it will not be changing with respect to time or all throughout the size, shape and density will be remaining as a constant.

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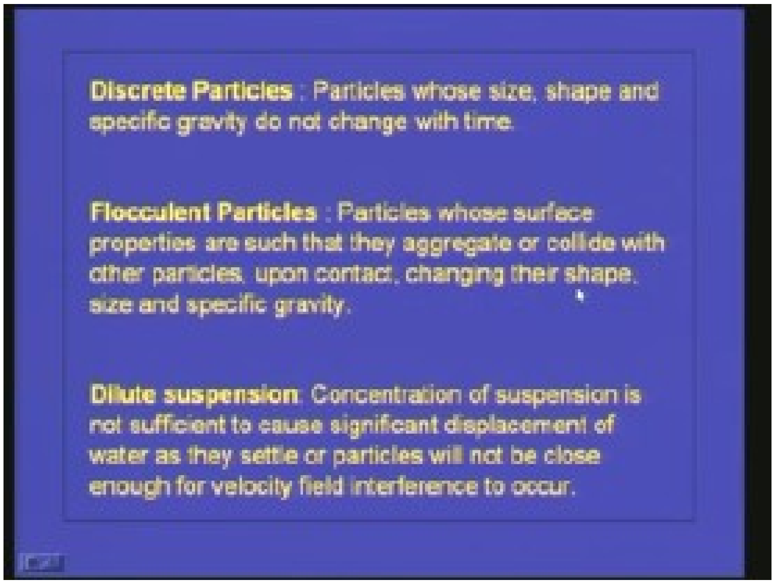

But coming to the flocculent particle those are the particles whose surface properties are such that they aggregate or collide with other particles upon contact, because of this one they change their shape, size and specific gravity. This often occurs in water treatment especially in coagulation flocculation system. We have already discussed that if the suspension is stable with respect to the solids we have to make them unstable then remove the solids by settling.

Therefore, in coagulation flocculation, if you are interested in removing the colloidal particle how can we make them unstable? We have to add some chemical agents which can change their surface properties and make them agglomerate. In the process what happens is the particles will be agglomerating so this agglomeration is a time dependent process so as more and more particles come in contact the agglomeration will be more so with respect to time what will happen is initially a single particle will be there and when it passes it will come in contact with the other particle so the size will be gradually increasing and with respect to time the size will be increasing and towards the end the size will be maximum.

Therefore, what is happening, here their shape, size and the specific gravity of the entire agglomerate will be changing with respect to time. Now coming back to the suspension we can classify the suspension into two different categories; one is dilute suspension and another one is concentrated suspension. What is this dilute suspension?

Dilute suspension is the one where the concentration of suspension is not sufficient to cause significant displacement of water as they settle or particle will not be close enough for velocity field interference to occur. That means the suspension is so dilute or the particle density or particle concentration is so low so each particle will be settling as independent particle or the velocity field of one particle is not being affected by the other particle or the concentration of the suspension is so low that it will not cause any significant displacement of water just like in soil mechanics where we talk about the consolidation test etc.

Therefore because of the weight what happens is whatever water that's entrapped in between the particles will be getting displaced so that type of a thing will not be happening in dilute suspension.

What is a concentrated suspension?
Concentrated suspension is the suspension which doesn't have these properties. that means the concentration is so high that each particle cannot act as independent particles or the velocity field of one particle is being affected by the other particle and there will be displacement of water because of the weight of the particles, because it is so dense one particle will be sitting over the other particle and it will be compressing the entire system so water will be getting displaced. So based upon the type of the particle and type of the suspension we can classify the settling into different categories.

This figure shows it clearly.

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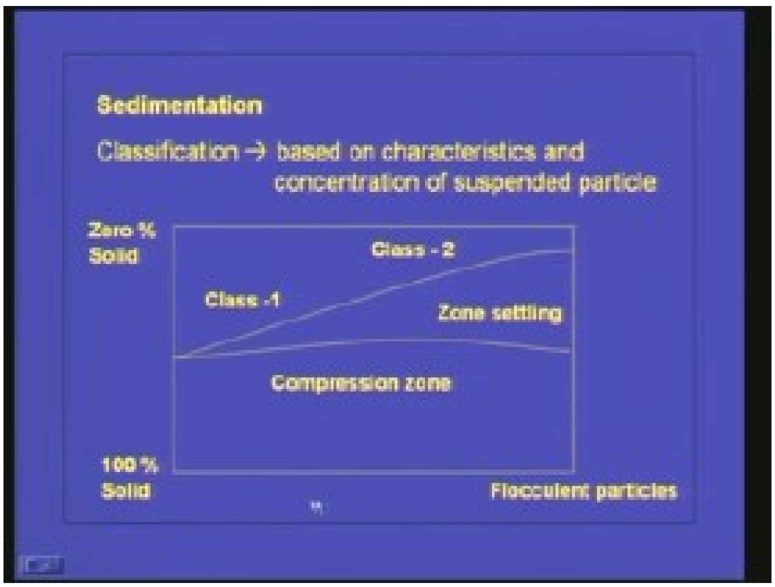

The y axis gives the percentage solid starting from 0 to 100 percentage and this side represents the discrete particles and this is flocculent particles (Refer Slide Time: 9:20). So if the concentration of particle is low and the nature of particle is discrete then we call the settling as class one or type one whereas if the concentration of the suspension is low and the particles are of flocculent nature then we call it as type two or class two settling.

When we talk about water treatment mainly we come across these two types of settling; class one or type one settling is very common in primary sedimentation tank where we usually remove the sand, silt and clayey particles and type two settling is common in coagulation flocculation or clary flocculator where we add alum and coagulate and flocculate the particles and we remove these flocs so that is an example of class two or type two settling.

In zone settling the concentration of the solids are relatively high so the particles will be fully interfering the velocity field of other particles so the particle cannot settle as independent particle so they will be settling as a group. If you keep this suspension in a quiescent condition in a cylinder then we can see that a clear zone is developing and that clear zone will be coming down very slowly. That's why it is known as zone settling.

In environmental engineering point of view this zone settling is very common in wastewater treatment systems. For example, in activated sludge process after the aeration tank we have to go for sludge removal so that is taking place in this zone settling mode.

And coming to compression settling either it is discrete particle or flocculent particle if the concentration is very high then we will be having compression settling because the weight of the particle will be displacing the water and because of that compression settling is taking place. So this type of settling is very common when we go for sludge thickening. these two settling we will be discussing in wastewater treatment portion and we will go in detail about class one and class two or type one and type two settling today.

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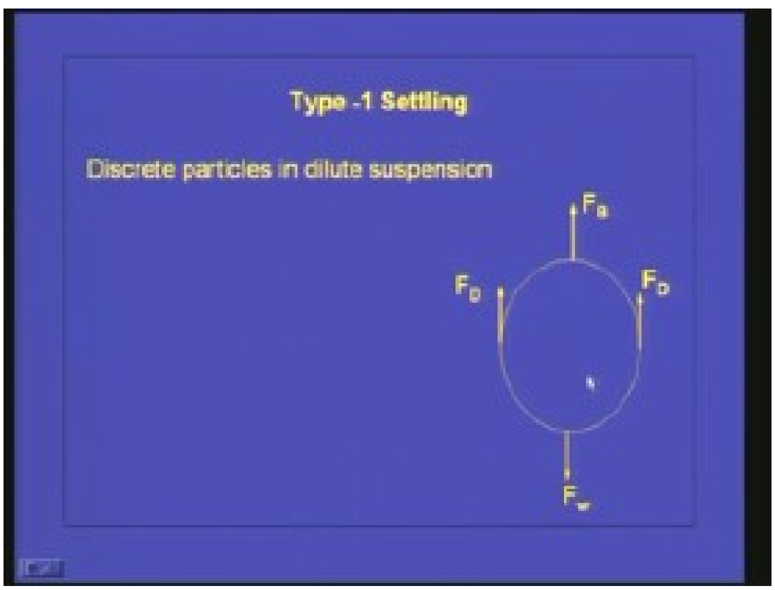

First we will discuss about type one settling. The significance or the property of this settling is these are discrete particles and they are in dilute suspension. So imagine if one particle is put into the liquid so what are the forces that will be acting on the particle immediately? Definitely the gravity force will be acting on the particle because of the weight and gravity and another force is the buoyant force. According to the Archimedes principle it is equal to the volume of water displaced by this particle. So we can find out what is the total force or the net force acting on the particle. But once the particle starts moving there is yet another force coming into picture that is the drag force because of the viscous friction experienced by the particle. So based upon that one we can find out what is the actual settling velocity of the particle if it is in a suspension.

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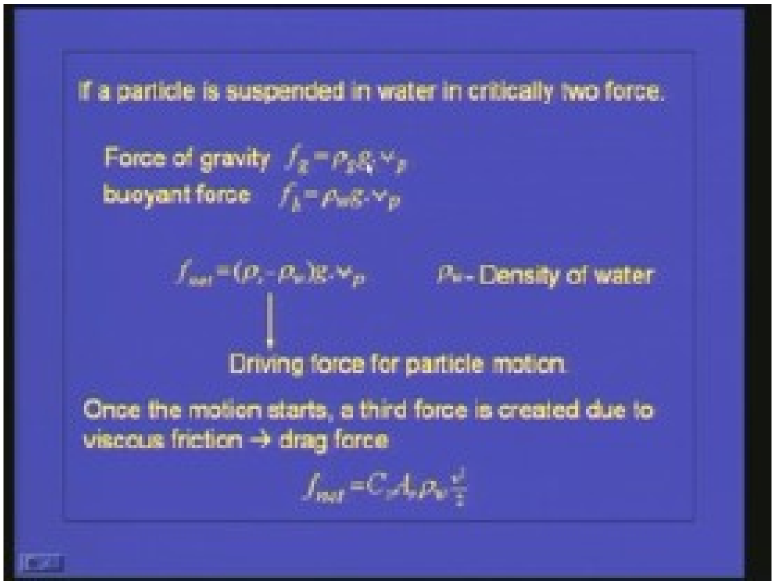

The force of gravity we can easily find out using this equation. This is rho_g into g where g is the acceleration due to gravity and v of particle. That means volume into rho will be giving the mass and mass into acceleration will be giving you the force of gravity and buoyant force is nothing but rho_w which is the density of water and g acceleration due to gravity and volume of particle because it is equivalent to the weight of water displaced because the volume of water displaced will be equal to the volume of the particle that's why we are taking VP here.

So if that particle is in suspension as such, if it is not moving, then the net force acting on that one is the difference between this force of gravity and buoyant force because we have seen that both of them are acting in opposite direction; one is in the downward direction and another one is in the upward direction. So the net force is rho_p minus rho_w into g into V_P. If the particle density is equal to the water density or rho_p is equal to rho_w this term will be equal to zero so net force acting on the particle will be zero so there will not be any motion, the particle will be staying in the exact location where it was.

But most of the time what is happening is the particle density will be much higher than the density of water so this will be acting as a driving force and the particle will start moving downwards. Once the motion starts the particle is moving through the liquid so a third force is created due to the viscous friction. The viscosity of the water will be acting on the particle so that will be opposing the motion the particle is moving in the downward direction and the frictional force will be acting on the upward direction so this is the third force getting introduced into the system. This force is known as drag force.

So drag force, this is wrong, this is drag force (Refer Slide Time: 15:12) we can find out using this formula; C_D AP rho$_w$ into v squared by two; this AP is the exposed surface area of the particle and v is the velocity with which it is moving.

So at steady state what will happen is, initially it was having a net force because of the difference between the gravity force and the buoyant force so it will be moving at a particular velocity but the drag force is acting upon that one so the acceleration will be decreasing with respect to time and after a certain stage the system will be at steady state that means both the forces will be equal that means the net force as well as the drag force. This is a steady state condition. That means gravity force minus buoyant force will be equal to the drag force. So we can write like this; rho$_p$ minus rho$_w$ into g into V_P is equal to C_D A rho$_v$ squared by 2. So, from that one how can we find out the settling velocity. We are interested in this V this is the settling velocity.

Initially we will talk about spheres. We assume that the solution having solids, all the solids are of spheres so we can find out what is the ratio between this V_P because V_P is coming here and A_P is coming here what is the ratio of this V_P and A_P so volume of sphere is nothing but four by three pi r cube and when we consider the drag force the cross sectional area comes into picture so we take the cross sectional area of sphere will be, so this is pi d pi r square so this is d by 2 and this is d by 2 so we will be getting the ratio as 2 by 3d so we can find out this V squared by 2 which is nothing but 4 by 3 g rho$_p$ minus rho$_w$ into d by C_D by rho$_w$. Thus, we are finding out what is this V squared by 2.

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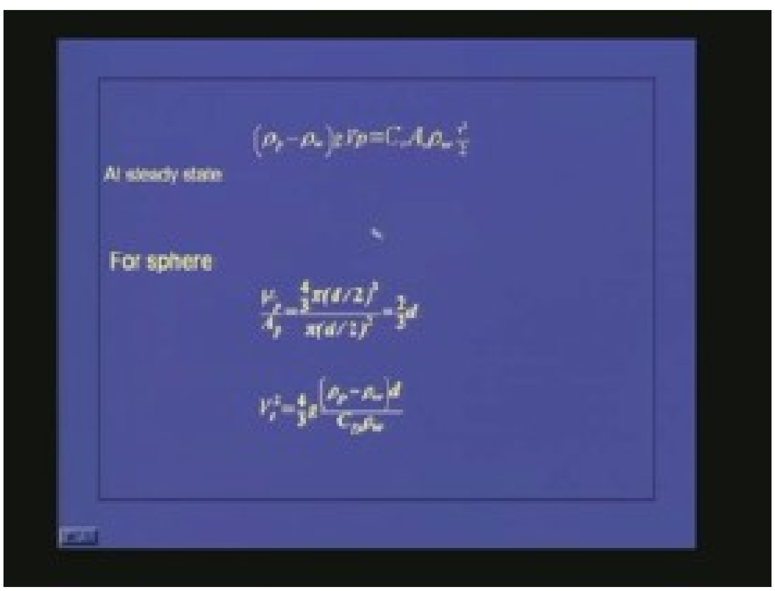

Now if you see in this equation we know rho$_p$; we know rho$_w$ and we will know the diameter of the particle and g we know but the only unknown is C_D which is the coefficient of drag. So how can we find out the coefficient of drag? It depends upon the nature of flow. The coefficient of drag will be varying in laminar condition, turbulent condition and transition and so on. It was seen that C_D is equal to 24 by Re if it is a laminar flow and it is 3 by Re raised to half plus 0.34 in transitional and 0.4 in turbulent. First we have to see, what is the type of flow we have, then depending upon that one, we have to find out the exact value of C_D and if you can substitute that value in C_D we will be getting the settling velocity or terminal settling velocity.

Now we will see what this Reynolds number is. It is nothing but rho$_V$d by mu and we have to include a factor five it is nothing but the shape factor.

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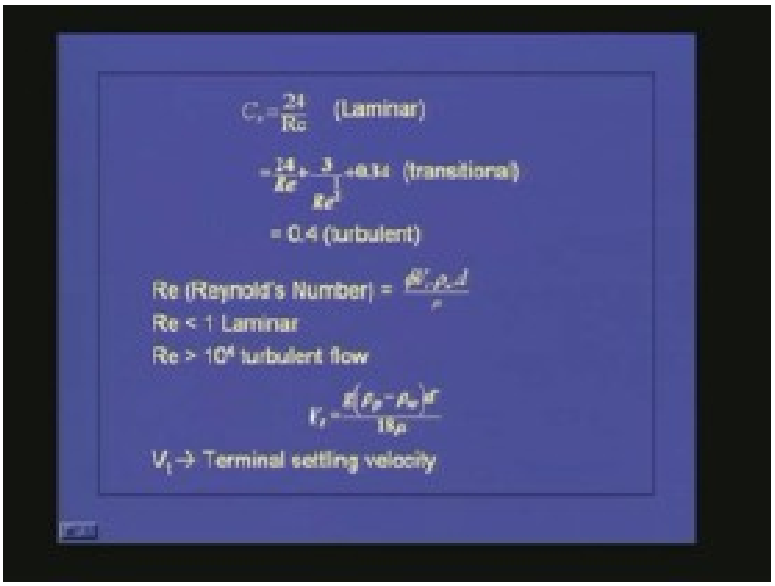

What is this laminar region? If Reynolds number is less than 1 we consider it as laminar and if Reynolds number is greater than 10:4 it is turbulent flow. So if you consider laminar flow and substitute C_D is equal to 24 by Re and Re substituted by 5 into V_t rho$_w$ d by mu and we assume that the shape factor for spheres is 1 then we will be getting V_t equal to g rho$_p$ minus rho$_w$ d squared by 18 mu where V_t is the terminal settling velocity so we can calculate the settling velocity of particles in discrete suspension. Or this law is known as Stoke's law. Hence, by using Stoke's law we can find out the settling velocity of the particle in a discrete in a dilute suspension of discrete particle or in type one settling.

Therefore, if you know the settling velocity and if we can find out the time required for the particle to travel in a given distance then we can design our settling tank in such a way that the particle will get enough time to settle.

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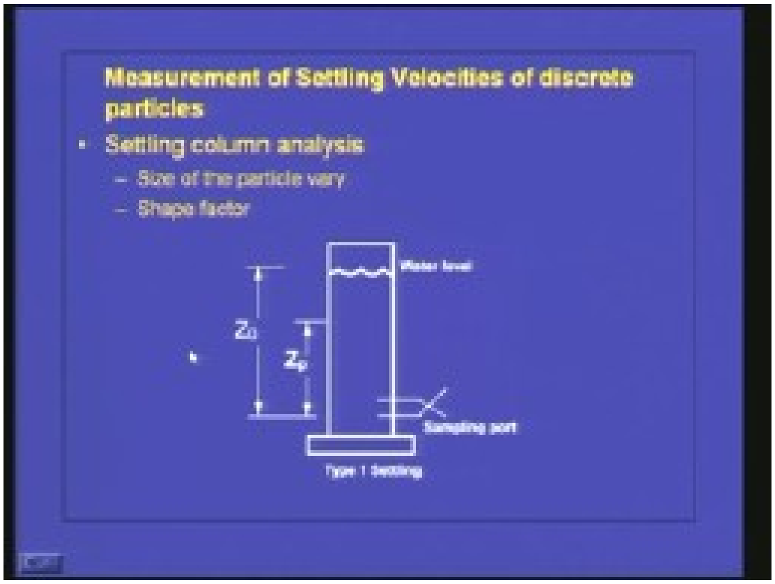

But coming to reality what is happening is, whatever particles are present in water will not be having uniform size, uniform density and uniform shape so how can you go for the theoretical measurement of settling velocity, it is impossible. Or, if you calculate the setting velocity theoretically and we use it for design you will not be getting the required efficiency. So what we usually do is we conduct settling column analysis in the laboratory and use that data for the design of sedimentation tanks for type one settling. So how can we conduct the settling column analysis.

This is a very simple test. what we have to do is we have to take a settling column of around 2 to 3 meter depth and a diameter of 10 centimeter or more because if you go for very small diameter the wall effect will be there because the particle diameter will be there and if the particle diameter and column diameter does not meet a specific ratio the settling will be affected by the wall, that is known as wall effect so we have to take the settling column in such a way that there is no wall effect and it will depict the sedimentation tank in the field.

So what we have to do here, this is your suspension (Refer Slide Time: 21:33) which we have to clarify and we assume that the liquid level in the column is Z_0 that means the height of the liquid column in the settling column is Z_0 so we are assuming that a particle is here in the top where Z_0 equal to 0 and it has to come up to this region then the particle is removed from the system, now, if we are giving a time of T_0 then we can find out what is the velocity? Velocity is nothing but the distance traveled by time of travel so we can find out that one. This is Z_0 because Z_0 is the distance it has to travel to get removed because this is the zone. We assumed that once it reaches in this zone the particle is not going to come back to the solution again or the particle is literally removed from the system. So the velocity is nothing but Z_0 by tu where tu is the time taken to travel which is nothing but the Z_0 distance so this V_0 is nothing but the average settling velocity.

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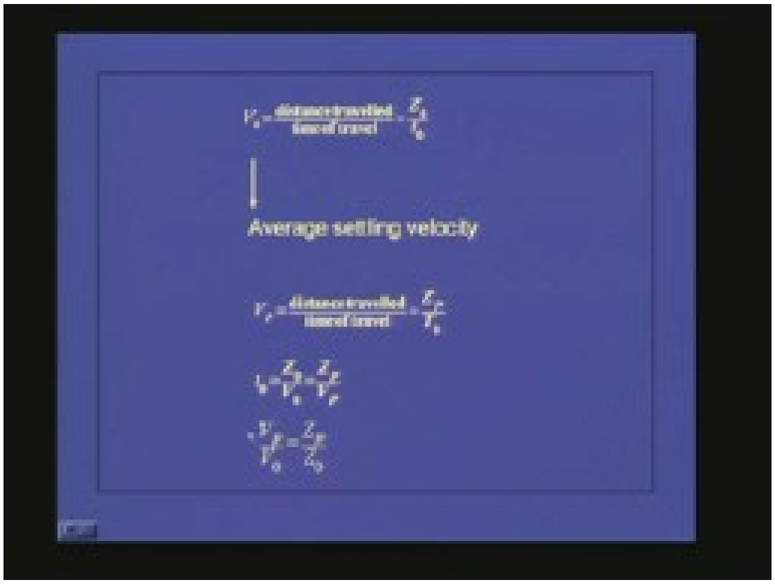

Again we will consider another particle, the particle is somewhere here and we are giving the same time as T_0 to this particle also Z_P so what will be the settling velocity of that particle; whether it will be higher than the particle whatever we have considered here or the settling velocity of this particle is less than that. the first particle whatever was here at the top of the settling column it took T_0 time to travel Z_0 distance but the second particle is taking the same time T_0 to travel a distance of Z_P. So naturally the settling velocity of this particle z which is at a height of elevation of Z_P will be lower than the settling velocity of the particle which is in the top. So, V_P we can find out which is the distance traveled by time of travel that is Z_P by T_0. We know that both the time is equal so we can equate the two terms Z_0 by V_0 because T_0 is same and Z_0 by V_0 is equal to Z_P by V_P or if you want to find out the ratio of velocities of those two particles which took the same time to get removed from the system or took the same time to reach the bottom of the settling column we can find out the ratio of their velocity V_P by V_0 is equal to Z_P by Z_0 so ratio of velocity is proportional to the height at which the particles were.

From this one we can make some conclusions. If we are giving T_0 time for the sedimentation tank for the removal of particles then all the particles with the settling velocity V_0 or higher than V_0 will be getting removed from the system and the particles which is having a settling velocity V_P less than V_0 will be getting removed if it is at a height Z_P or lower than that because if the settling velocity is VP that means the velocity is lower than V_0 and the particle at Z_0 with the velocity of V_0 and a particle at Z_P with the velocity of V_P takes the same time to reach this region where we assume that the particles are removed.

So, if the particles are having only a velocity of V_P and if you want them to get removed from the system at a time T_0 then the particle should be either at Z_P or at an elevation lower than Z_P because if it is somewhere here (Refer Slide Time: 25:44) it will be getting removed before T_0 and if it is somewhere here it will not be getting removed before or within T_0. So those are the things concluded here.

All the particles with diameter greater than or equal to d0 and settling velocity greater than or equal to V_0 will be removed from the system because the time required for their settling will be lower than d0. And if dp is less than d_0 or V_P is less than V_0 will be removed provided its original position is below point Z_P.

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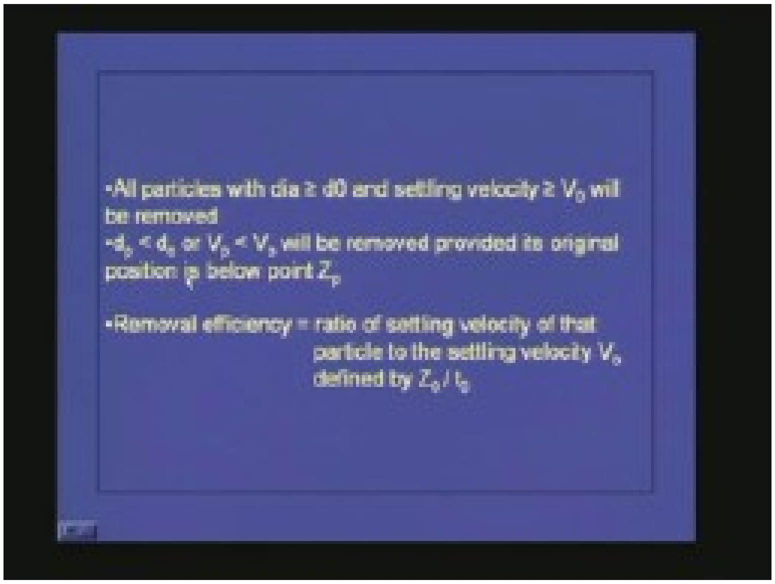

Point Z_P was taking the same time as T_0 to get removed so if the velocity is less than V_0 then it should be below the point Z_P. Removal efficiency is a ratio of velocity of that particle to the settling velocity V_0 defined by Z_0 by T_0 where T_0 is the detention time provided in the sedimentation tank.

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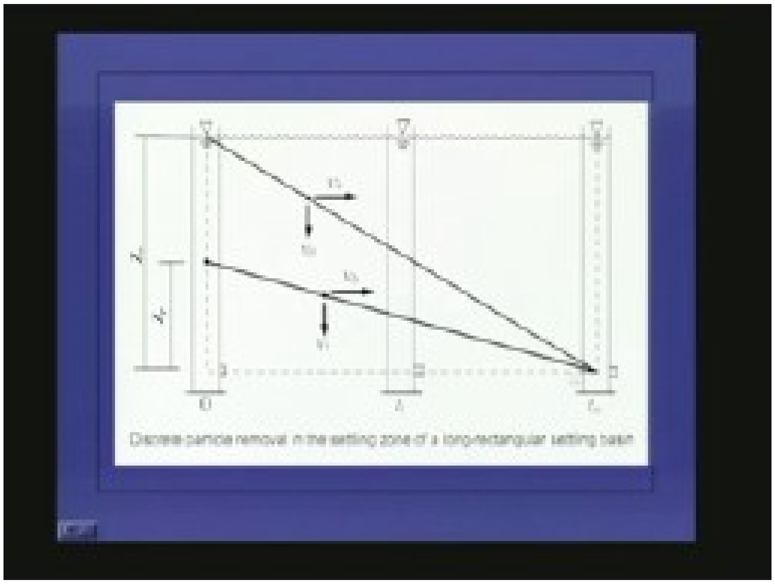

This is the pictorial representation of that one, when a particle is there in a sedimentation tank and when water will be flowing continuously to the tank it will be having a horizontal component of the velocity same as the horizontal velocity of the tank and it will be having a vertical velocity that is the settling velocity. So the particle will be taking a part like this (Refer Slide Time: 27:12) this is the resultant of the V_h which is the horizontal velocity and V_0 which is the vertical velocity. So, if the particle is here and it is having a vertical velocity of V_0 and the horizontal velocity that is the same throughout the tank so that particle will be getting removed at this point. So we are assuming that any particle which comes up to this point is getting removed.

We are considering another particle here, it has to travel only this much distance vertically so it takes the same time; the V_h is the same and it is having the settling velocity V_P so the resultant velocity is like this so within that same time since the elevation it requires to travel is less so it will also be getting removed. Thus, by using this concept we can find out the efficiency of a sedimentation tank because the sedimentation tank will be having different sizes and different shapes of particles homogenously mixed from the top to bottom. Actually our design will be suitable for removing particles with a particular diameter from the system so the particles of that same diameter will be getting removed from the system no matter however it is positioned.

But if the particle diameter is lower than the design or the settling velocity is lower than the designed settling velocity it doesn’t mean that the entire particle will remain in the tank. Depending upon the position of that particle a portion of that one will be getting removed, that is what we are going to discuss here.

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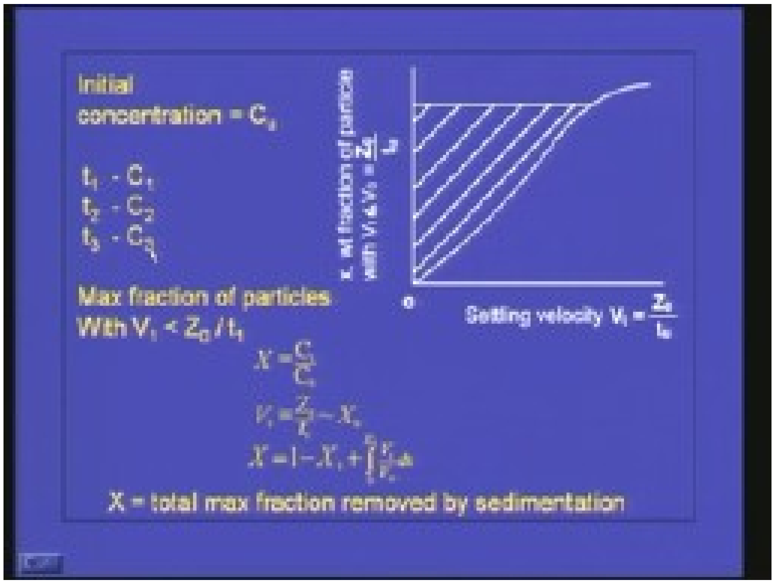

We have a homogenous suspension with an initial concentration of C_0 and what we do is, we allow that suspension to settle, then at different time intervals we take the concentration whatever is remaining in the solution, whatever is settled is already removed from the system and whatever is remaining will be there in the suspension. So at t_1 the concentration of suspension is C_1; at t_2 the concentration is C_2 and at t_3 the remaining concentration is C_3 so these are the remaining particles in the suspension. Therefore, maximum fraction of particle with V_1 that is Z_0 by t_1 equal to X is equal to C_1 by C_0 that much particle is removed in the system and the fraction of particle with V_0 is nothing but Z_0 by T_0 that is having a fraction equal to X_0.

Or we can represent like; this is the settling velocity (Refer Slide Time: 30:03) that is nothing but V_t equal to Z_0 by time. At different time intervals it is having different settling velocity and here we are finding out the fraction of particles which is remaining in the system. Remaining in the system at time t_1 is nothing but C_1 by C_0; at time t_2 is nothing but C_2 by C_0 and at t_3 it is C_3 by C_0 but at time V_t is equal to the design settling velocity what will happen is we are giving enough time for the fraction of particles whatever is present and that will be getting removed completely and this region (Refer Slide Time: 30:53) the particle that is not in the top is in the in between portion of the sedimentation tank so a fraction of that one will be getting removed. Hence, we can find out what is the total removal efficiency that is nothing but up to here X_0 this is our design settling velocity so X_0 is the fraction of particles remaining at that tank so the particle removed from the system is nothing but 1 minus X_0 so 1 minus X_0 particles are completely removed from the system and this portion up to X_0 a portion of that one will be removed depending upon the position of the particle that was initially there.

We can find out the efficiency by summing up this one; 1 minus X_0 plus integral of 0 to X_0 into V_t by V_0 in to dx. V_t is the settling velocity of that particle and V_0 is the design settling velocity and dx is this incremental length here. So if you take the area of this portion this will be giving you the fraction of particles which is having a settling velocity lower than the settling velocity.

Now, coming to the discrete settling now another thing is that, though we provide a tank depth of 2m or 3m actually speaking in discrete particle settling the depth of the tank is not at all important. How can we show that one? The velocity or the settling velocity at any time or any particle is nothing but tank depth divided by the detention time. And detention time if you want to define you have a sedimentation tank and you know what is the volume of the sedimentation tank and you have to treat a particular volume of water and the water will be flowing into the sedimentation tank at a constant rate so we assume that the inflow rate is Q. That means this much of meter cube water per second or per day or per hour is coming into the tank. So what is the detention time available in the tank it is nothing but the volume of the tank divided by the flow rate. If the volume is hundred meter and we are pumping water at 10 meter per cube hour then he detention time it is nothing but 100 divided by 10 means ten hours. Similarly here we can find out what is the detention time, it is nothing but depth divided by tank volume by flow rate so it is again depth.

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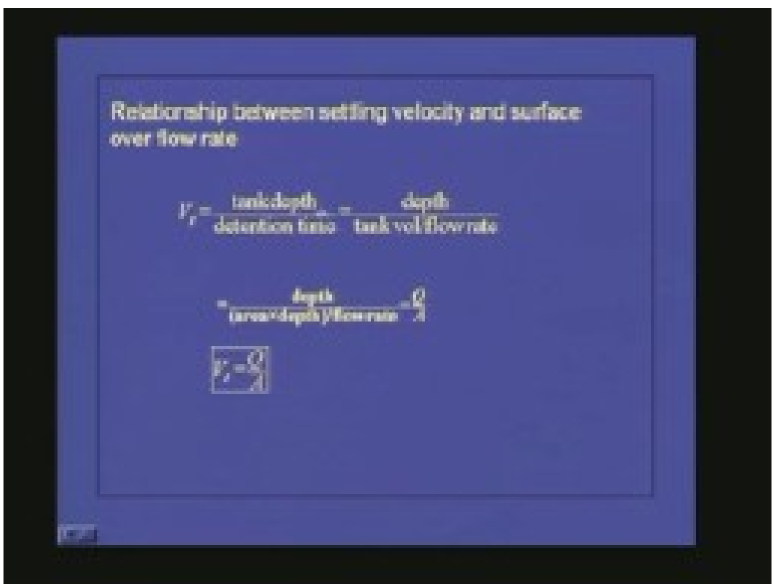

And tank volume is nothing but area into the depth the flow rate. So we can find out like this; depth and depth will be getting cancelled so you will be getting Q by area. So the settling velocity of the sedimentation tank is a function of the flow rate and surface area of the tank, this area is nothing but the surface area of the tank not the depth.

This is very important in the design of a sedimentation tank especially when we deal with type one settling. In type one settling the design parameter is not the detention time it is this parameter Q by A it is known as surface overflow rate.
And the settling velocity of any particle is numerically equal to Q by A or the surface overloading rate.

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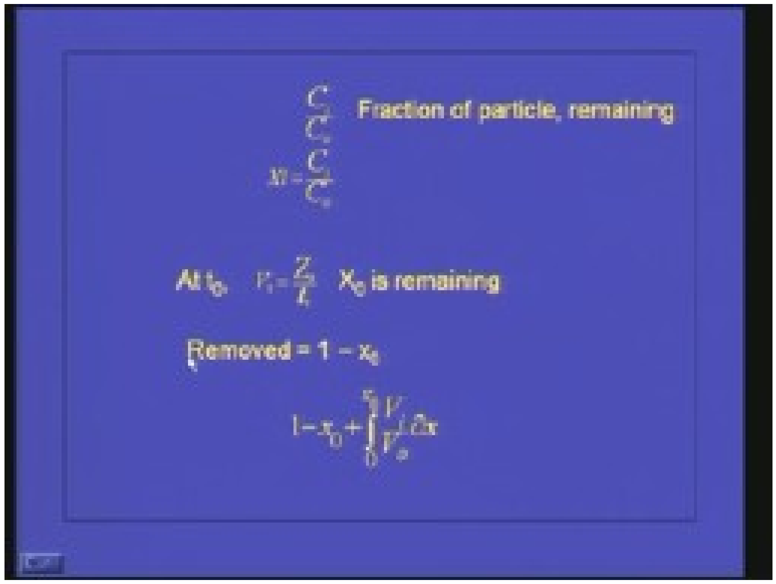

This is the thing we were explaining earlier; what is the fraction of particle remaining and at T_0 X_0 is remaining at T_0 X_0 is remaining so the removal is 1 minus X_0 which we have already discussed. So whenever we go for discrete particle settling we can even increase the efficiency of the tank by reducing the depth.

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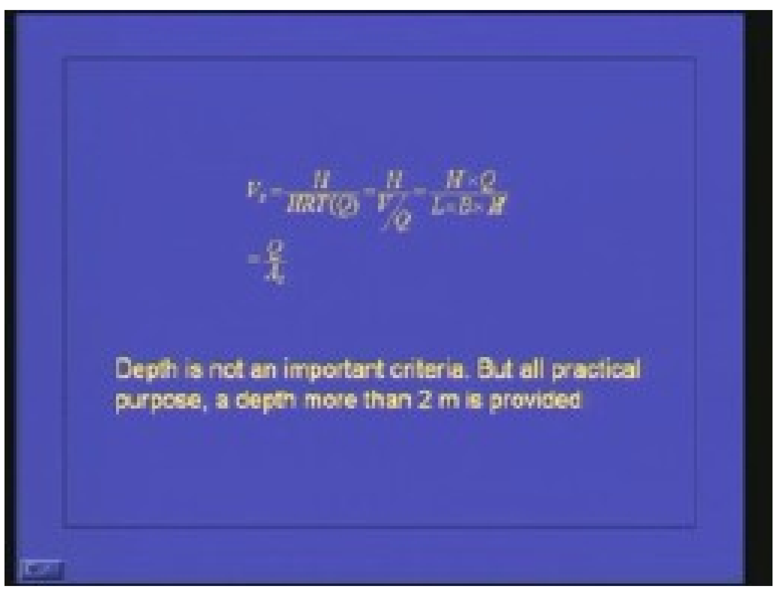

Using this concept only the high rate sedimentation tanks like tube settlers, plate settlers etc are being constructed. We are assuming that if you have a tank of two meter depth and if you provide many plates parallely the surface area will be increasing depending upon the number of plates so you will be getting Q by As a very small number so naturally the tank efficiency will be increasing.

Nowadays many high rate sedimentation tanks which is used for the discrete particles and settling have come up. We will be discussing about them towards the end of this lecture.

We have discussed about type one settling, discrete particle, how to conduct the column study and get the settling velocity and if you want to get the real efficiency of that system how can we find out what is the total efficiency of particle removal in type one settling.

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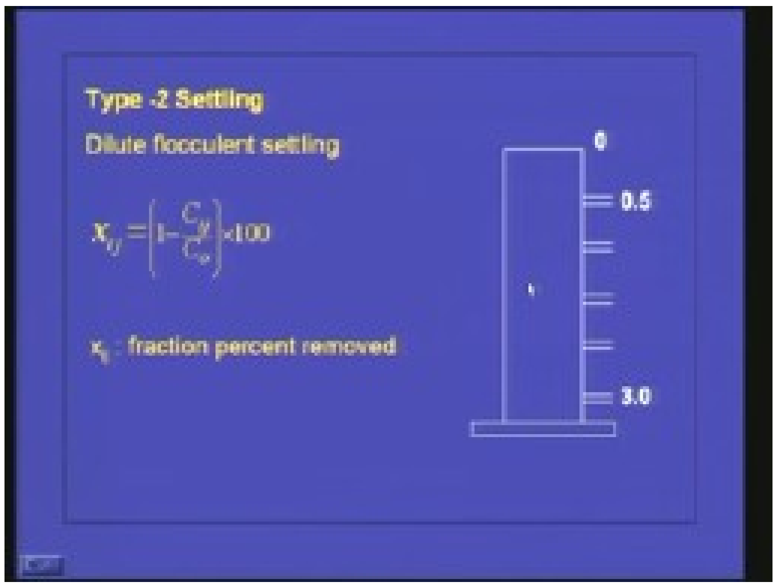

Now we will come to type two settling. Type two settling is dealing with dilute flocculent settling. In water treatment this type of settling is coming in clary flocculators. After the addition of coagulants the colloidal particles are destabilizing and because of the flocculation or because of the velocity gradient we provide in flocculation these particles come in contact with each other and they agglomerate and as a result the particle size will be increasing with respect to time and they will be settling. So naturally in type two settling the depth of the tank is an important criteria because if you give more time more and more particles will be agglomerating provided there is a velocity gradient available.
So we cannot predict the removal efficiency in case of type two settling by theoretical means. We have to conduct laboratory experiments using the same type of suspension and find out what is the settling velocity and what is the removal efficiency. And if you want to find out that one again we have to go for column settling analysis.

Here the column settling analysis is slightly different. In the column itself we have to make some modifications. In the earlier case we had only one port to collect the sample. But here what is happening is we have to collect the samples at different depths. What will happen with respect to depth the particle velocity will be increasing particle size will be increasing so we want to get a clear picture of what is the rate of particle or what is the amount of particle removed at different heights and at different times that is what is being done in type two settling.

So here instead of finding out the amount of particle left over in the system what we do is we find out what is the amount of particle removed from the system at a given depth and at a given time. That is what this gives; xij, xij is the fractional percent removed from the system that is nothing but 1 minus cij by C_0 into 100. cij is the concentration of particle left in the column at the port i and time j. It is a time dependent and position dependent value. So we can find out xij and what is the fractional removal at different ports.

Therefore, if you want to conduct the experiment first you fill the column with the suspension whose particles we want to remove and we want to design a sedimentation tank. Initially we mix it homogeneously so that in all the parts of the column you will be having uniform concentration and find out what is the C_0, C_0 is nothing but the initial concentration of the particles present in the system.

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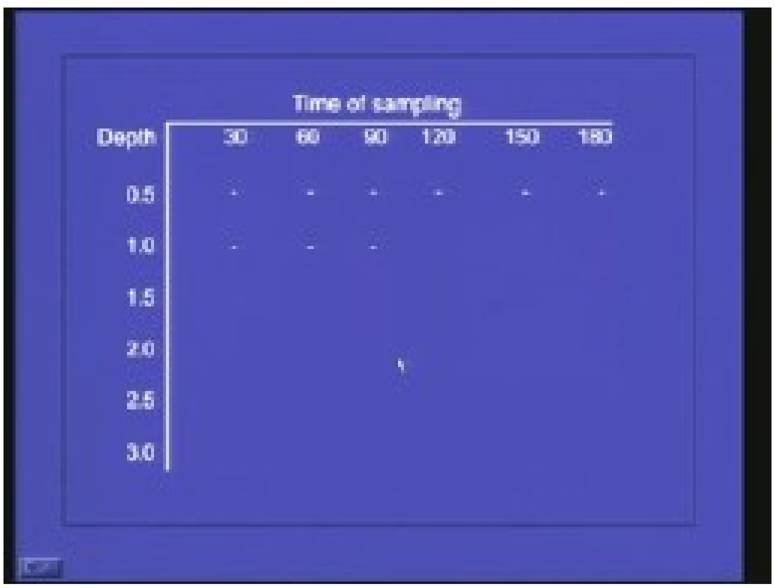

These ports are located at 0.5m distance. So starting from 0 to 3 you have five different ports and what you have to do is you have to take the samples at different time intervals, say 20 minutes or 30 minutes so every thirty minutes you have to take the samples from all the five ports then you have to find out what is the cij and corresponding xij you can find out and you can tabulate the results like this depth and time so you will be getting different concentrations. Hence the concentration cij whatever you are getting is the concentration whatever is remaining in the system. Then using this formula we can find out what is the fraction removed at a particular time.

Therefore, using this data we can draw this curve, this is known as ISO removal lines from the settling analysis. Thus, you have different depths like 0.5, 1, 1.5, 2.0, 2.5, 3 and so on and different time so you will be getting different percentages. So you just find different percentages corresponding to the depth and the next step what you have to do is draw a line passing through the same percentage removal so at different depths you will be getting the same percentage say 15 percentage so you will be getting different values of 15. Now you join all those points. Similarly 30 percentage, 45 percentage, 60 percentage, 75 percentage etc depending upon how [o……41:05 sive] unit you can draw the ISO concentration line for all ten percentage removal efficiency, twenty percentage, thirty percentage etc.

Once these ISO removal lines are there how can we find out the settling tank efficiency? It is very easy to find that out. The significance of these ISO removal lines, these ISO removal lines gives the settling velocity of that fraction of particle. That means this is the fraction of particles or the type of particles which gives 15 percentage removal (Refer Slide Time: 41:42) and this is the fraction of particle which gives 30 percentage removal and this is 45 percentage and this is 60 percentage and so on.

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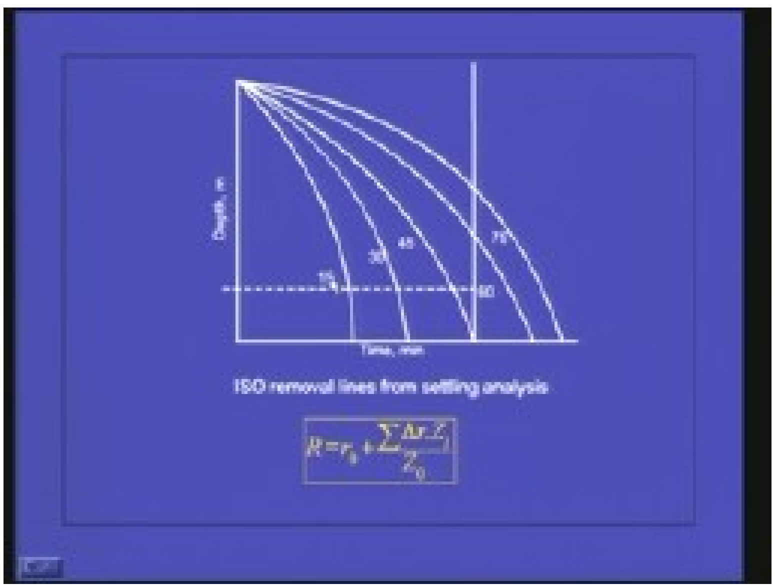

So, at any point of this ISO removal line if you take the tangent that will give the velocity of that particular fraction of suspension or that particular fraction of solids. So you can see the top, if you take the tangent the slope is low, as it comes down the slope is increasing and towards the bottom the slope is very steep or the settling velocity is very steep. From this one it is very clear that the depth of the tank is very very important in case of flocculent suspension. Why the velocity is increasing with respect to depth? As I have already discussed the particle will be growing in size with respect to time so initially the velocity is low and with respect to time the velocity is increasing and finally you will be getting very high velocity. This is true for all these lines. As we go (Refer Slide Time: 42:50) the velocity is increasing from the top to bottom.

How to find out the efficiency? Already we will be having an idea; this is the maximum detention time we can give for the sedimentation tank. We can mark that point here because here we have the time in minutes. So say you are planning to give only 90 minutes in your sedimentation tank that means only 1.5 hours for the sedimentation so you mark this point here so what does it mean so this 45 percentage line is touching at that point. That means if you give ninety minutes of time you will be getting 45 percentage removal and some fraction of this 60 percentage, 75 percentage file etc will be also getting removed at that time so what you have to do is draw a perpendicular to that point which is the design time then we can find out the efficiency as R is equal to r_0 r_0 is the fractional removal at that point plus sigma delta r into Z_i by Z_0. That means we know the removal efficiency is depending upon the velocity. As we have seen in discrete particle settling it is depending upon the velocity V_P by V_0 or it is a ratio of dp by d0.

So, if you take this portion you take what is the delta r, delta r is nothing but 75 minus 60 divided by 100 you will be getting 0.15 so 0.15 and you have to take the depth up to the mid point of this point that is your Z_i so it will be around 2.5 and your Z_0 is 3. Similarly, this point you take your r is 7, this portion r is 60 minus 45 equal to 15 and this portion also r is 75 minus 60 that means 15 by 100.15 and you find out what is the Z_i corresponding to this point from this graph and Z_0 is 0 so like that you find out for all the lines. So you will be having a line for 80 percentage, 90 percentage something like that so you find out all the fraction and sum it up so you will be getting the removal efficiency.

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These are the important things. ISO concentration lines represent the maximum settling path for the indicated removal slope gives the settling velocity. As the timer increases size increases so settling velocity also increases. This is the most important thing (Refer Slide Time: 45:48) how to find out the settling efficiency. Initially we decided to go for 90 minutes and you are getting only 60 percentage of removal but you are intended to get 80 percentage of the removal; how can you achieve that? The only thing is you have to change your detention time. Say you go for 120 minutes so two hours then you see what is the removal efficiency you can get. Like that you can find out what is the efficiency maximum you can get and based upon this data you can design your sedimentation tank.

As I have already mentioned, zone settling and compression settling because it is not coming in water treatment because in water treatment we are dealing only with type one settling and type two settling. So this zone settling and compression settling we will discuss in detail when we talk about wastewater treatment.

Now we will see the different types of sedimentation tank which are commonly employed. We can go for either long rectangular tanks or circular tanks or solid-contact clarifiers. The most commonly used sedimentation tanks are long rectangular ones and circular tanks are also being used.

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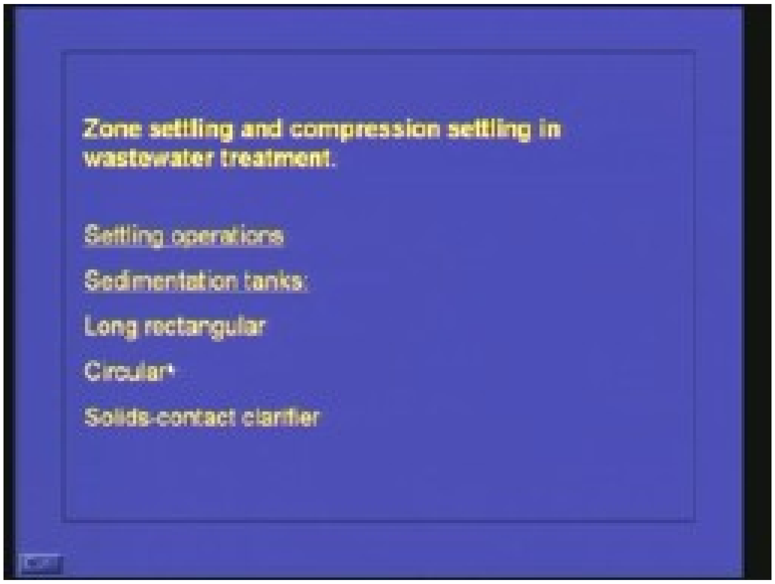

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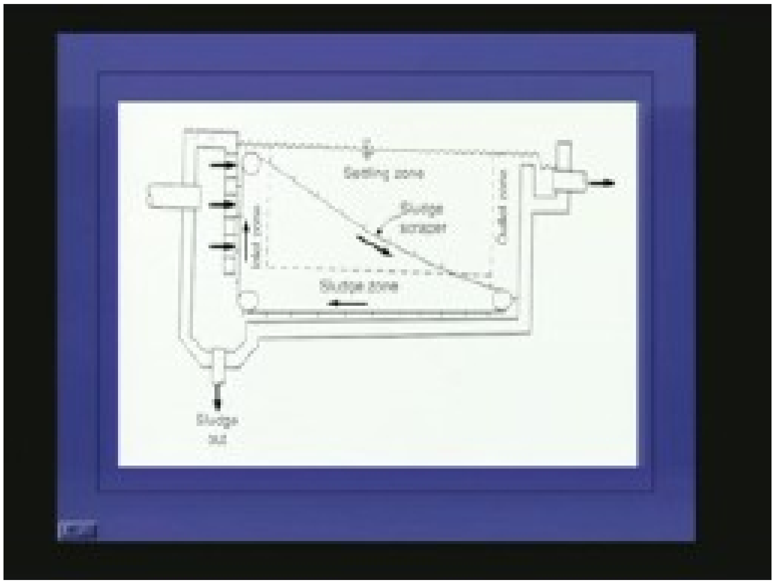

What are the important parts of a sedimentation tank?

It will be having an inlet region and an outlet region and this is the settling zone (Refer Slide Time: 47:26) and whatever is settled in the sedimentation tank we cannot allow it to accumulate there, we have to remove the solids from the sedimentation tank otherwise what will happen is whenever there is a flow there will be disturbance and there is also a chance where whatever settled sludge is present in the sedimentation tank will come up so we have to remove the settled sludge periodically.

Usually this is the sludge removing mechanism and the removed sludge will be coming to a hopper and from here it will be pumped out. So these are the common features of a sedimentation tank. We will see each part of this sedimentation tank in detail. Before that one we will see the common dimensions of a sedimentation tank.

As I have explained we can go for long rectangular tanks circular ones or solid-contactors though solid-contactors are not commonly used in our country. But in hydraulic point of view long rectangular basins are always advisable because they are more stable and flow controller control is easier. We also know about the velocity profile, it is constant because the particle will be moving with a resultant velocity of the horizontal velocity and the vertical velocity so we can find that out.

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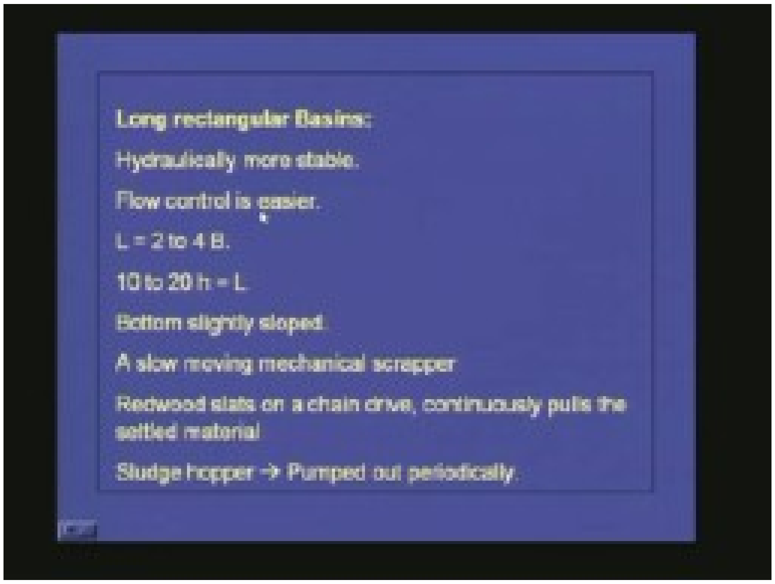

The length of the tank usually varies from two to three times the width of the tank. Usually the length is 10 to 20 times the height of the tank and always the bottom of the sedimentation tank will be slope slightly because it will facilitate the removal of the sludge. As we discussed it will be equipped with a slow moving mechanical scrapper to remove the sludge and usually redwood slats on a chain drive is usually used for the removal of the sludge. What will happen here is, a chain is there and this wooden planks are there and this one will be continuously moving so whatever sludge is settled here will be scrapped by the scrapper and it will be moved and it will be coming here (Refer Slide Time: 50:00) and from here we can pump it out easily. This is the sludge hopper.

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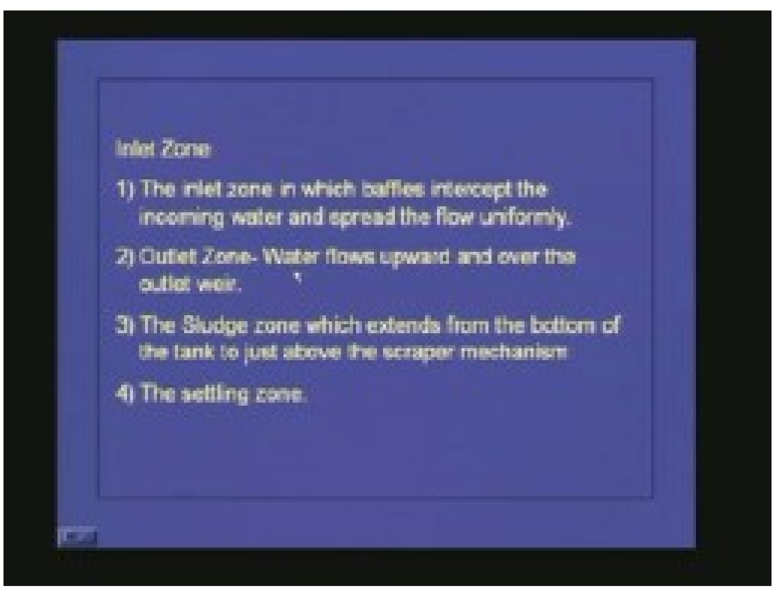

The inlet zone is another important thing because when we allow the water to enter into sedimentation tank, if lot of turbulence is there the sedimentation tank will not be functioning properly and whatever sludge that is settled in the bottom of the sedimentation tank will be disturbed and it will be coming up so your sedimentation tank efficiency will be drastically decreasing. Therefore, we have to design the inlet zone properly. The major objective of the inlet zone is allowing water to enter uniformly without much disturbance into the sedimentation tank.

For outlet zone also we have to be careful. Because if you take out the water at a high rate again it will be creating turbulence in the tank and the quiescent condition will not be maintained in the tank so that will be influencing or that will be deteriorating the efficiency of the tank.

Sludge zone is extended from the bottom of the tank to just above the scraper mechanism and the last one is the settling zone. We have seen surface loading ad detention periods. For sedimentation tank design, especially for discrete particle or type one settling, we have to design the tank for surface loading not for the detention period because surface loading rate is nothing but the settling velocity. We have to give enough time for the particle to settle properly so the design parameter is surface loading.

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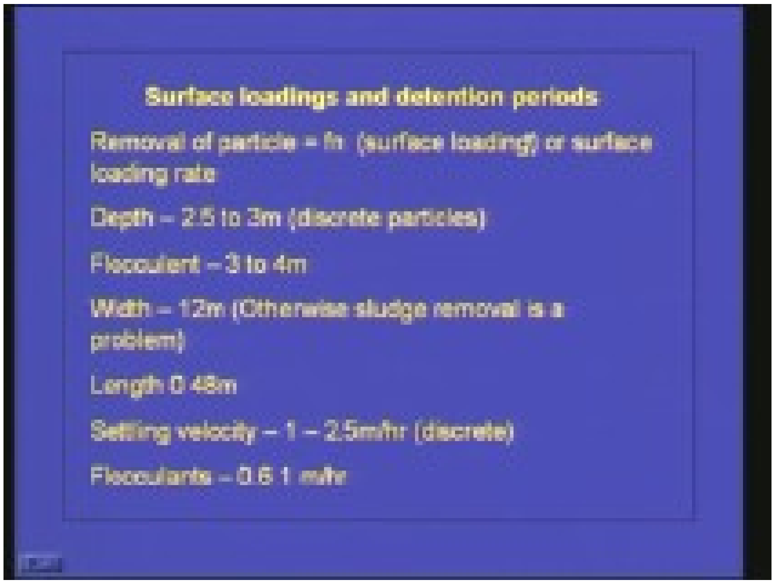

For discrete particles settling we usually give a depth of 2.5 to 3m in the sedimentation tank. Though we say that the depth of the tank is not so important we usually give a depth of 2.5 to 3m and if it is flocculent settling we give a depth of 3 to 4m because depth is also important and usually the width of the tank we give around 12m because if you reduce the width tool to a too low value then the sludge removal becomes a problem. The length is up to 48m which we usually go for and settling velocity for discrete particle the value ranges from 1 to 2m per hour and whereas the flocculent settling it is 0.6 to 1m per hour because for discrete particle usually it is sand or silt or clay so the specific gravity will be very high so naturally they will be having a high settling velocity whereas for flocculent particle the density will be lower so the settling velocity will be less.

The remaining portion of the sedimentation process we will discuss in the next class. Now we will see the things we have discussed in today's class. We were discussing about the different types of solids and we have seen that the solids can be divided into discrete and flocculent and this division is important when we design the sedimentation tank because the property of the solids are so different so unless we know the property of the solids the design will not be proper. then we were discussing the different types of suspension and there also we have seen that basically we can classify it into two categories either dilute suspension or concentrated suspension and based upon the particle nature and the suspension we can classify the settling into four categories that means type one settling, type two settling, zone settling and compression settling. As far as water treatment is concerned we are dealing only with type one settling and type two settling.

Compression settling and zone settling we mainly use in wastewater treatment so that portion we will be discussing in wastewater treatment. Then we have seen that in discrete particle we can find out the settling velocity using Stoke's Law so we will be getting the theoretical settling velocity. but in practical conditions or if you want to design a sedimentation tank for a particular type of solids we cannot directly use Stoke's Law because the diameter of the particles will be varying and the shape of the particle will be varying because Stoke's Law is developed for uniform size and uniform shape particles and we are assuming that it is spheres so we have to conduct laboratory studies. This study is known as settling column analysis. Using the settling column we can find out what is the removal efficiency.

So if you design a sedimentation tank for a particular settling velocity all the particles with that settling velocity will be removed completely and some particles whose settling velocity is lower than the design settling velocity also will be removed because all the particles will be homogeneously mixed the tank from the top to the bottom. So if the location of the particle is lower than the top level then the time required will be less to reach the sludge zone. Once it reaches the sludge zone we assume that it is settled.

Now, coming to the flocculent settling the depth of the tank is important and the column settling or settling column analysis is entirely different. Here what we have to do is we have to find out what is the concentration of particles being removed at each height at different time intervals and by analyzing the data we can draw the ISO concentration lines and using this one we can find out what is the efficiency of the system. We have seen the different types of sedimentation tanks we usually employ. The most preferred one is long rectangular tank because hydraulically this is the most stable one and circular ones are also being used commonly. The most important parts of a sedimentation tank are; inlet zone, outlet zone, settling zone and sludge zone. The bottom of the tank will be always incline inclined to remove the sludge and the sludge will be coming to a sludge hopper from there we can remove it easily. Thus, the details of the design and the values of surface overflow rate, weir loading etc we will be discussing in the next class.