Water and Waste Water Treatment

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Lecture -14

Waste Water Treatment Plant: Sedimentation and Basics

Hello everyone. Welcome back to the latest lecture session. Until now we have been discussing the variables of interest to us, the relevant flows of interest to us and how the flows change with time or day. Then we moved on to discussing the headwork's or the preliminary treatment as in we know that sewage typically is collected by gravity at the sewage treatment plant. If that is not permitted due to the relevant terrain sometimes you will have what we say pumping stations.

At this particular sewage treatment plant, you obviously need flow of water from one unit process to the other. You typically do not want to pump it each time. You will want the flow to go by gravity or be driven by gravity. Thus, in the head works you are going to have the relevant pumping station to pump the relevant water to the relevant head. Such that you know you are going to also take into account the friction losses and such.

Then we looked at what do we say removal of grit and such coarse screens and so on and so forth. But in the context of grid removal, we looked at anyway briefly anyway sedimentation. Grit relatively much bigger particles compared to the other suspended particles let us say. We talked about sand we talked about coffee beans and so on and so forth. We talked about core screens or such.

But we also talked about what we say rectangular what we say basins where you have laminar flow conditions with a weir at the end proportional weir or such. Such that the flow is maintained constant flow such that you know scouring of only the suspended particles or organics is taking place. But the relatively heavier particles which are or which is the grit is settled down, we looked at this.

In that context we looked at this term or came across this term sedimentation. In the next couple of sessions or at least in this session we are going to look at sedimentation in greater detail. Because that is one of the primary treatment process that is going to remove most of your suspended particles in wastewater or water let us say depending upon the kind of water. Let us look at what we have here.

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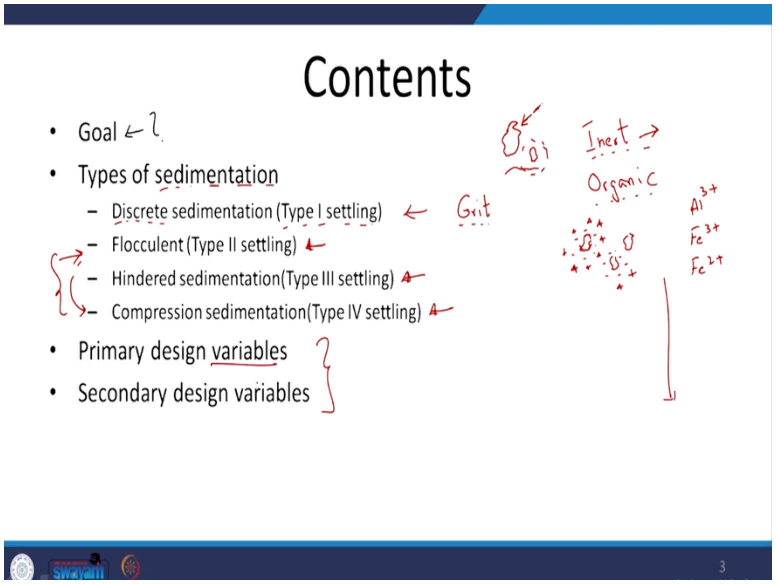

Contents

- Goal
- Types of sedimentation
  - Discrete sedimentation (Type I settling)
  - Flocculent (Type II settling)
  - Hindered sedimentation (Type III settling)
  - Compression sedimentation (Type IV settling)
- Primary design variables
- Secondary design variables

Grit

Inert

Organic

Al^{3+}

Fe^{3+}

Fe^{2+}

As I mentioned we are going to look at sedimentation and contents at least of this particular session and probably the one after this session. Why is it that I or what do I want to achieve out here. We have suspended particles relatively bigger, some smaller you know some of these are inert some of these have organic content. Inert if you do not remove them, they will cause issues down the line in the other unit process by settling out.

You are going to have relatively lesser effective volume also can lead to abrasion and wear of tear of your relevant machinery. You do not want the inert content and typically the bigger or heavier inert content we remove during preliminary treatment or during the head works. That is when we already remove most of the bigger inert particles. But there will be some suspended what we see not particles and also which are relatively smaller than grit.

You will also have some organic content which is suspended. Organic content, how do we remove typically? Typically we will remove that by biological process where microbes in the presence of oxygen are going to catalyze this reaction of oxidation of your waste. Our waste is the microbe's food, our waste by oxygen. Oxidation of our waste by oxygen and the reaction is catalyzed or you know the kinetics is improved by the enzymes released by the microbes.

But here obviously oxygen needs to be supplied. We are going to have to pump oxygen or air into the relevant biological process. When we are pumping air obviously you know that is going to be a costly affair. If you have the relevant sludge treatment available out there, you can remove significant fraction of your organics here, not a lot but a significant fraction of your organics here.

You know less load is available on the relevant or in the biological process bringing down the cost. But again, it is not as straightforward as that you have to look at other aspects too. We are going to look at sedimentation. In the context of sedimentation depending upon the type of flow conditions, the type of particles you have different types of sedimentation. One is discrete and we looked at this in the context of grit removal.

When we say discrete, people know what discrete means. In this context we can think of it as what will be settling of the relevant particles independent of each other. The particles which are settling do not interact with the other particles, that is layman's terms. Typically, we see this when we are looking at removal of grit. But again, type one settling again all these are ideal case, what we say scenarios.

You are never going to have one, what do we say perfect example of discrete sedimentation. The second one which we are now going to look at in the context of primary treatment of wastewater as in when you want to remove these particles, let us say which are not as big as great or not as heavier as grit. You are going to look at flocculent settling where in these smaller particles relatively smaller particles let us say.

By themselves they will take too much time let us say to settle down. What do you add a coagulant or if the particles are good enough to be or not good enough or are going to settle down without the presence of our need for a coagulant. That is also one possibility especially in wastewater. But let us look at both the aspects. Typically, these have charge and they do not let them come together.

They repel negative charge, they repel. If you want them to come together and coagulate and then form flux, what do you need to do. You need to add charge, so you are going to add the opposing charge which is a positive charge. That is where when you look at addition of this is plus, that might not be clear due to the way it is being written. I am going to add a coagulant Al^{3+}, Fe^{3+}, Fe^{2+}.

Now I am going to neutralize the charge on these collides so coagulation and then these colloids now come together and form flocs. Flocs and then these flocs settle down and that is typically the case in flocculent settling. Depending upon the size without the addition of coagulant two you can have flocculent settling. This is also seen in case of your primary sedimentation tank.

But that will also encompass what do we say hindered or compression sedimentation but we look at that later. Flocculent settling type one and type two settling. Then hindered and compression which will look at in some detail later. Once we understand these relevant types of segmentation, we are going to look at the relevant variables and look at the relevant design let us say. What are the variables of interest and how do we design let us see.

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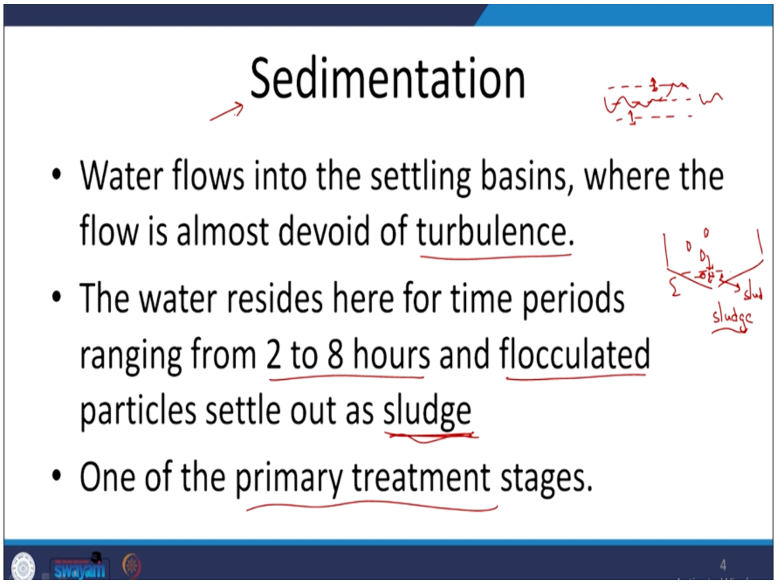

Sedimentation

- Water flows into the settling basins, where the flow is almost devoid of turbulence.
- The water resides here for time periods ranging from 2 to 8 hours and flocculated particles settle out as sludge
- One of the primary treatment stages.

Sedimentation, so water as we know flows into the settling tanks where the flow is devoid of turbulence. We are talking about turbulence and laminar flow. What do I understand by that? Laminar flow more or less it is sequent flow as in the flow goes through in layers where you know there is little interaction between one layer to the other. There is little to no interaction between one layer to the other.

But turbulence let us say you know you see that usually let us say when you have monsoon or you know during the monsoon season and if you look at the canal you are going to look at turbulent conditions let us see. It is the flow is going to be violent you are going to have eddies and such and you know it is not certainly going to be laminar. Here we are talking about at least in this context.

We are talking about what is this now, laminar flow. Why if you have turbulence, you will be covering velocity and such you know the particles are never going to be able to settle down. The eddies let us see they are going to keep the particle up in suspension. Because they are going to be what we say carried along with the fluid or fluid flow. Typical retention times are from 2 to 8 hours and what happened to these flocs or the particles they settle out.

That is what we refer to as sludge. If this is my sedimentation basin, so the bigger particles let us say are going to settle down. Thus I have this settled out, what do we say fraction we are going to call it as sludge. One of the primary treatment stages what sedimentation. Here we are not looking at coagulation or flocculation that you are going to look at as and when needed. Here we are just talking about settling basins only.

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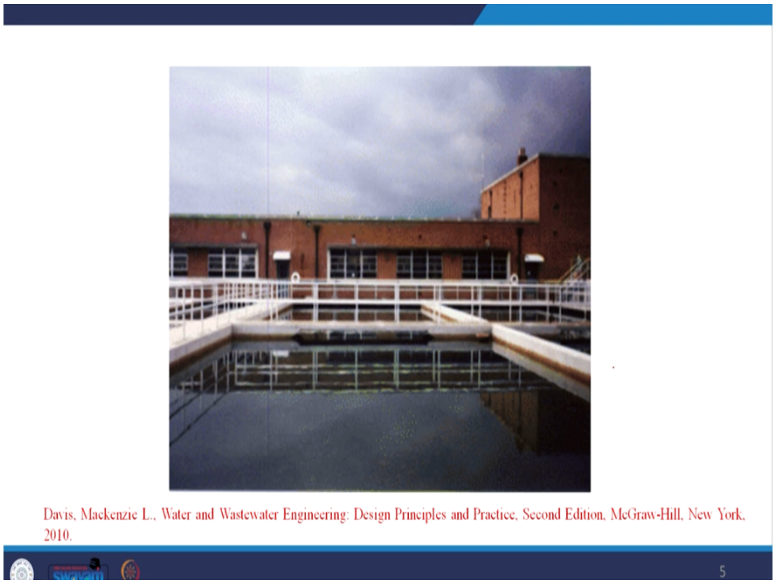

Davis, Mackenzie L., Water and Wastewater Engineering: Design Principles and Practice, Second Edition, McGraw-Hill, New York, 2010.

Let us move on. This is a typical picture obviously the flow you see is pretty still. If you have turbulent conditions obviously your particles are not going to what we say settled down or maybe think of what we see in this room here. If I bring some dust in my or fine dust in my hand and throw it up into the air as in keep it in suspension. Now the room is entirely locked there are no fans running here and such.

The particles are going to settle down, let us say relatively faster. But once I throw this dust up into the air and I turn on the fans I am going to create turbulent conditions. The particles are going to remain in suspension for a much greater period of time. That is one aspect or one way to understand why we are going to maintain these laminar flow or cuisine conditions typical sedimentation basins.

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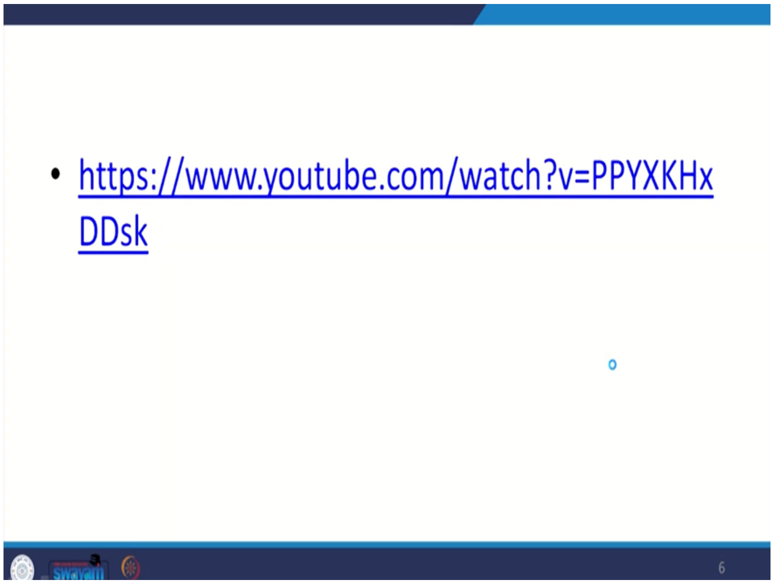

- https://www.youtube.com/watch?v=PPYXKHxDDsk

Let us move on so I wanted to show a video here.

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American water works association is providing us with this video and just let us look at what we have. I will try to give the voice over. Sedimentation and clarifiers. What is happening here as you can see the relatively bigger particles were settled down. I will fast forward as deem necessary so relatively bigger particles or heavier particles are settling down.

I should not just say bigger and here you have relevant cuisine conditions or laminar flow conditions and you have the weirs here all along. That this velocity is or you know is more or less is in the laminar flow region. Let us see or this flow is in the laminar flow region. You are going to have the relevant settling during this particular period let us see. You can have rectangular or you can have circular, what do you say segmentation basins.

Let us I think we are going to look at the waves. Here you have the waves let us say. Yes different kinds of designs we will look at that later. An example of a circular one which we will come back to looking at we have a better picture here. We have the sedimentation circular sedimentation basin or circular clarifiers, let us see. That is what you see, there are two kinds of what do we say circular sedimentation tanks.

One is where the flow comes in through the center from the bottom to the top and flows radially or you know again perimeter what we say flows in from the perimeter. But typically in India I have seen that most people use the ones that come in from the center flow up and flow out. We will look at the relevant schematic or graphic later. This is what we want to look at. Particular what we say schematic of this sedimentation basin the circular sedimentation.

Water is coming in through here with the relevant suspended particles and this influence zone what is it that we are trying to do. We are trying to see to it that the velocity which is relatively higher here. By the time that it comes out here let us see, comes out here what is going to happen to that in the infinite zone what do we want to do? We want to see to that the velocity of water comes down or the energy is dissipated.

That is the major aspect, energy is dissipated and there is uniform distribution of your relevant, what do we say flow and the suspended solids. That is what we want to do in our influent zone. Then here we are going to have this settling zone. Please note this because we are going to make some assumptions later. This is where you know some particles are going to be settled down as the water flows radially from the center towards this effluent zone.

Effluent zone again the design has to be such that you know the particles that have settled out are not carried over into the effluent zone. That is something to keep in mind. Influent zone, effluent zone, settling zone and then we should also have another zone this is called the sludge zone. Let us see right where the sludge is collected and then you have the hopper here you see the hopper that is going to scrape your sludge and that is going to be collected.

The sludge that is collected at the bottom is going to be collected. What do we have given different kinds we can have them inside or such circular let us move on. Let me move on to one aspect I wanted to show. To increase the surface area available, we will look at why that is needed as in height of your; you know unlike what we might think height does not really play a role.

Height of your basin does not really play a role in determining the removal efficiency of your relevant what is this now settleable solids let us say. But the surface area does but again we will look at this later. To improve that you can have what we say plate collectors and such and that is what we are going to look at different plate collectors here. That the you know height let us say is going to be pretty less not let us say meters or so but only a few centimeters and you will still have the removal. That is what you see here.

More surface area the settleable solids are going to settle down in this plate or circular collectors and they are going to settle down out there. Depending on the relevant design the sludge is going to be carried out. Enough of that let us move back to our presentation, so that is one schematic.

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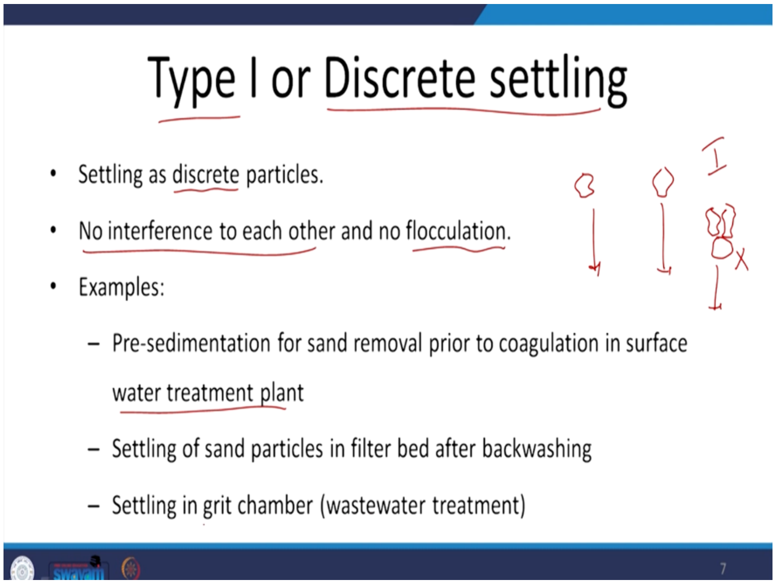

Type I or Discrete settling

- Settling as discrete particles.
- No interference to each other and no flocculation.
- Examples:
  - Pre-sedimentation for sand removal prior to coagulation in surface water treatment plant
  - Settling of sand particles in filter bed after backwashing
  - Settling in grit chamber (wastewater treatment)

Different types of settling the ones we looked at until now were mostly flow type two settling. But I just wanted to show the kinds that we are discussing here. Type one or discrete settling what are the major aspects as I mentioned. The particles are not interacting with each other. They settle as discrete particles. No interference and more importantly when there is no interference with each other no flocks are formed.

One particle is here they just go through the like this as in they do not come together and they do not form flocks. This does not happen in type 1 settling, let us say discrete settling. Where does this occur and pre-sedimentation for sand removal, grit removal or coagulation in surface water plant let us see, in surface water plant. Filtering bed settling in a grid chamber of the wastewater treatment plant as we mentioned earlier.

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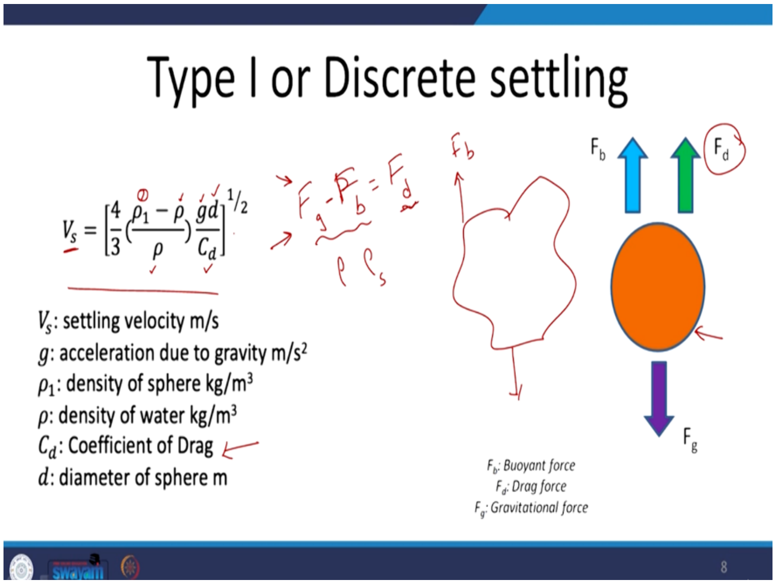

Type I or Discrete settling

$$V_s = \left[\frac{4}{3}\left(\frac{\rho_1 - \rho}{\rho}\right)\frac{gd}{C_d}\right]^{1/2}$$

V_s: settling velocity m/s

g: acceleration due to gravity m/s^2

ρ_1: density of sphere kg/m^3

ρ: density of water kg/m^3

C_d: Coefficient of Drag

d: diameter of sphere m

$F_g - F_b = F_d$

$\rho \quad \rho_s$

F_b: Buoyant force

F_d: Drag force

F_g: Gravitational force

As we know right gravity is pulling us down you know it keeps everybody down to earth. Here we are going to look at Stokes law which more or less again looks at what is the application of gravity. What do we have here. We have relevant particle of different any size let us say. What is going to happen, the gravity is going to pull it down and buoyancy is going to push it up.

$$V_s = [\frac{4}{3}(\frac{\rho_1 - \rho}{\rho}\frac{gd}{C_d})]^{1/2}$$

This particular drag force or let us say the frictional force on the relevant particle, gravity minus buoyancy. At the terminal settling velocity, when there is no acceleration will be equal to this. This force pulling it down will be equal to the frictional force let us see. You can think of that. We can just apply it and what is it obviously going to be depended upon it is going to be depend on the density of the water, density of the solid, the relevant shape, the relevant volume, the relevant surface area of the particle and then the coefficient of drag.

We can plug that in and get a relevant equation. For a spherical here, for a sphere right we can have the relevant what we say settling velocity which we will derive from this equation. That is going to be this. Let us look at what are the relevant variables here. Settling velocity or the terminal settling velocity of that particle. Obviously as we mentioned what is it going to be dependent upon gravity that is a constant.

But what are the relevant other constants here? Density of the sphere is a variable, obviously density of water is relevant constant and what else density of water out here, coefficient of drag and then the diameter of the sphere. As I mentioned we are modifying the equation we get from this particular deviation for a sphere let us see and that is what we have out here. This is applicable in general everywhere.

But again, we are going to look at applications in the context of sedimentation for laminar flow. Let us look at what we have out here.

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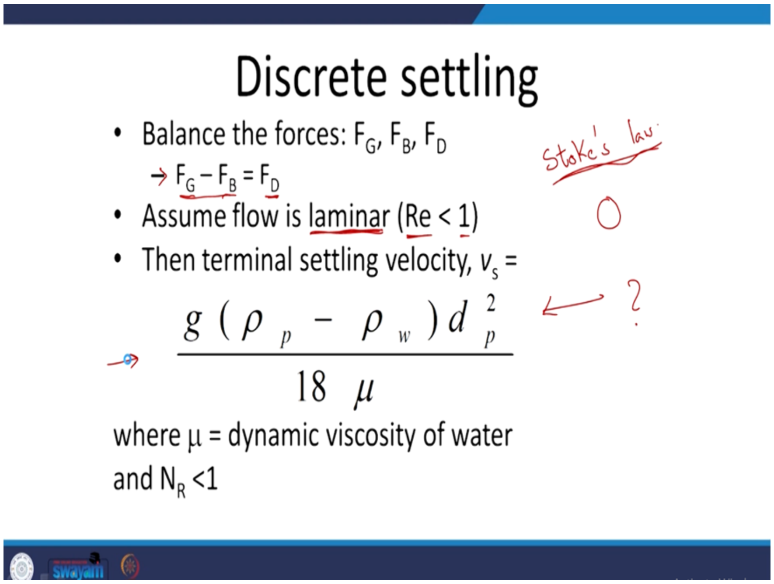

Discrete settling

- Balance the forces: F_G, F_B, F_D
  - → $F_G - F_B = F_D$
- Assume flow is laminar (Re < 1)
- Then terminal settling velocity, v_s =

$$\frac{g\,(\rho_p - \rho_w)\,d_p^2}{18\,\mu}$$

where μ = dynamic viscosity of water
and N_R <1

Stoke's law

?

Discrete settling so again as I mentioned the gravity and buoyancy is going to be, what we say, the force pulling it down or the particle being pulled down will be balanced by the drag force or the frictional force. Mr. Stoke, the Stokes law will give us this equation. But in which condition is this equation what do we say relevant let us see. It is relevant when the flow is laminar.

$$\frac{g\left(\rho_p - \rho_w\right) d_p^2}{18\mu}$$

In general, for determining whether a flow is laminar or turbulent or in between transitional flow, we look at the Reynolds number. If the Reynolds number is less than one the flow is deemed to be laminar flow. We will apply the Stokes law only when the flow is laminar and the particle is sphere.

That something for us to what we say keep in mind. Look at this and again you can look at this equation too let us see. That is what we have again only for laminar flow.

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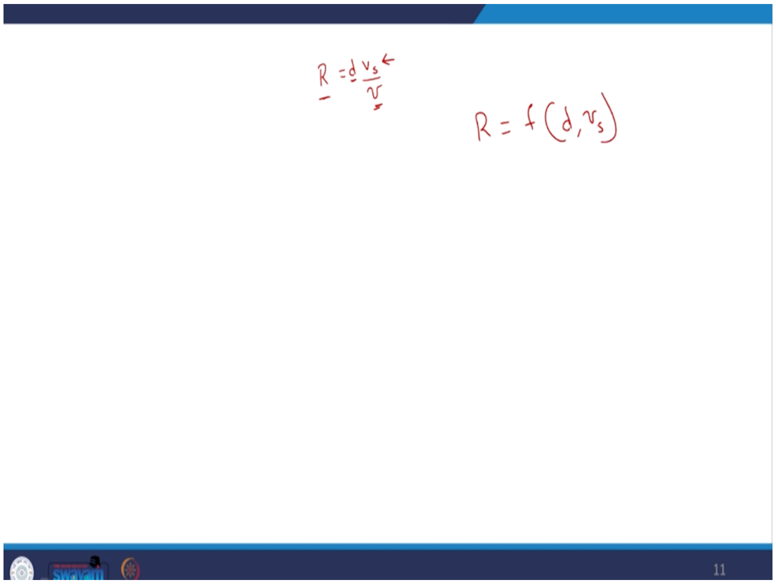

$R = \frac{d\, v_s}{\nu}$

$R = f(d, v_s)$

One aspect to note is that this Reynolds number is depends upon the diameter of the particle, the kinematic viscosity and the settling velocity of your particular particle. What does it depend upon let us see. Let us see water let us assume, this is constant function of the diameter and the settling velocity. Let us keep this in mind we will come back to this again.

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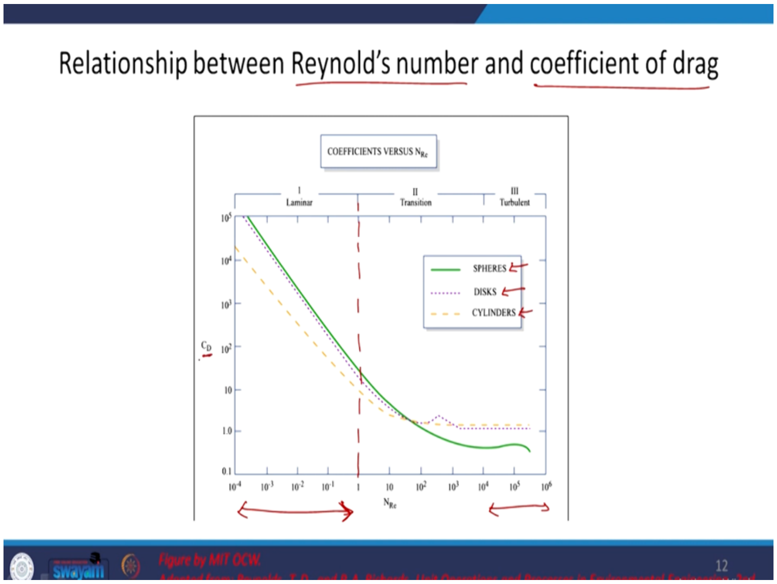

Relationship between Reynold's number and coefficient of drag

Figure by MIT OCW.
Adapted from: Reynolds, T. D., and P. A. Richards. Unit Operations and Processes in Environmental Engineering. 2nd

Here from this particular reference what do we have the relationship between Reynolds number and the coefficient of drag for different spheres, different types of particles spheres or different shape particles, discs and cylinders. Again, you can look at the relevant equation and understand this. You see that for differently shaped particles the behavior is going to be different.

Here we have the laminar region, when the Reynolds number is less than 1 and then here, we have the turbulent conditions let us see. Again, we are just trying to look at the different profile because as we see it is depending upon the shape of the particle 2. Here is the coefficient of drag which is decreasing with increasing Reynolds number.

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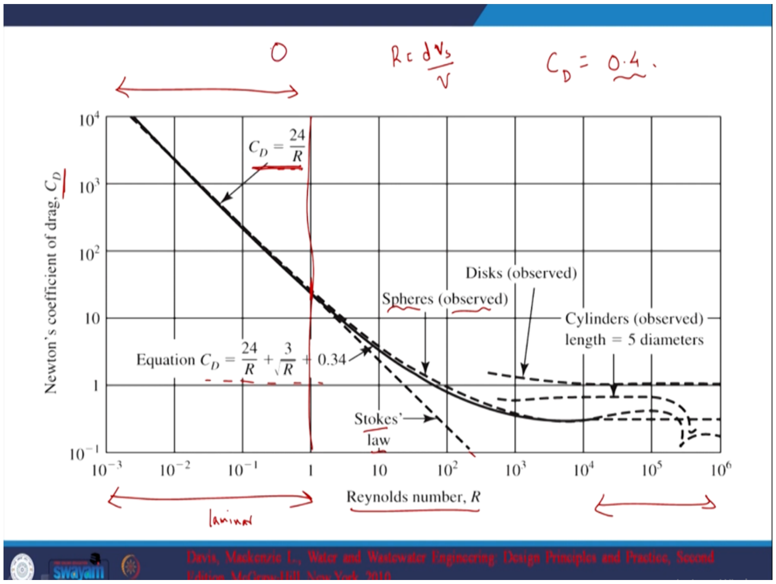

Davis, Mackenzie L., Water and Wastewater Engineering: Design Principles and Practice, Second Edition, McGraw-Hill, New York, 2010

This is from the Davis book. What do we have, we can calculate the coefficient of drag in terms of the Reynolds number. For relatively higher what do we say Reynolds number where the flow conditions are turbulent. Coefficient of drag will be something like 0.4, if I am not wrong, we can check this later. But in the laminar flow region, the relevant coefficient of drag will be equal to 24 by R.

$$R_e = \frac{dv_s}{\mu}$$

Again, coefficient of drag is 24 by R and we know that Reynolds number is equal to the diameter of the particle settling velocity of the particle by the kinematic viscosity. That is something to understand out here. What do we have, we have the equation for coefficient of drag in the laminar flow conditions. Coefficient of drag out here in the transitional flow and here we have the profile for the Stokes law which is applicable only in the laminar flow conditions.

We have coefficient of drag on the y axis and Reynolds number on the x axis. Here we have laminar flow and then some transitional flow and then turbulent conditions out here. What do we see, we see three kinds of data here at least in this particular initial what we say part of the graph, the initial half of the graph spheres observed and the relevant equation and then for the Stokes law.

We see in the laminar flow conditions obviously there is a good agreement between observed and the relevant loss and the equations. But then you see the divergence being apparent in the transitional and certainly in the turbulent conditions. In the type one settling we are concerned with the relevant laminar flow only and for spheres that something to keep in mind.

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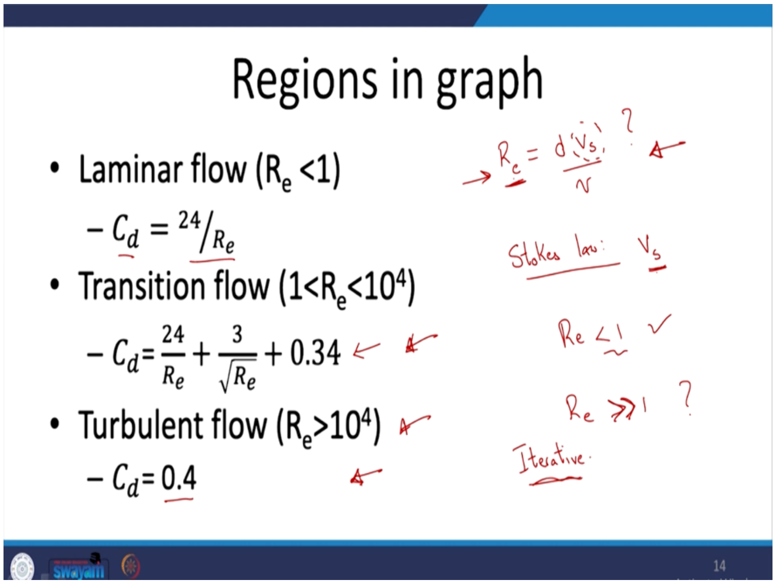

Regions in graph

- Laminar flow (R_e <1)
  - $C_d = {}^{24}/_{R_e}$
- Transition flow ($1<R_e<10^4$)
  - $C_d = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34$
- Turbulent flow ($R_e>10^4$)
  - $C_d = 0.4$

$R_e = \frac{dV_s}{\nu}$?

Stokes law: V_s

$Re < 1$ ✓

$R_e \gg 1$?

Iterative.

Let us move on, so laminar flow Reynolds number I mean quotient of drag is depend upon the Reynolds number and transitional flow and so on and so forth let us see. As I mentioned point 4 that seems to be the right value and we calculated the Reynolds number to be equal to not calculated, we know that it is equal to diameter of particle settling velocity by the kinematic viscosity.

$$C_d = \frac{24}{R_e} \qquad (R_e < 1)$$

$$C_d = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34 \qquad (1 < R_e < 10^4)$$

$$C_d = 0.4 \qquad (R_e > 10^4)$$

Now how do I get this settling velocity, so I have my Stokes law, Stokes law relatively simple. But as we know stokes law is applicable or very well applicable only in the laminar flow region that is what I see out here. Assuming laminar flow conditions I am going to calculate the stokes, I mean settling velocity from the Stokes law. For that particle shape and not shape size let us see, based on that I am going to calculate the trial Reynold's number.

If this trial Reynolds number ends up being less than 1, fine I can go ahead with my relevant calculations and such. But if this Reynolds number turns out to be more or much more than 1 then what do I do, it is an iterative process. With this Reynolds number I will calculate the coefficient of drag whether here or here. Then go ahead and calculate the relevant settling velocity from the Newton's equation if I may.

Then I will again calculate the Reynolds number and see whether that is what we say more or less applicable to my particular case or do I need to again change the relevant coefficient of drag. Then I will come up to a particular point again iteratively where I can come up with my or calculate my settling velocity and the Reynolds number. That is something that I can do out there and that is something to keep in mind.

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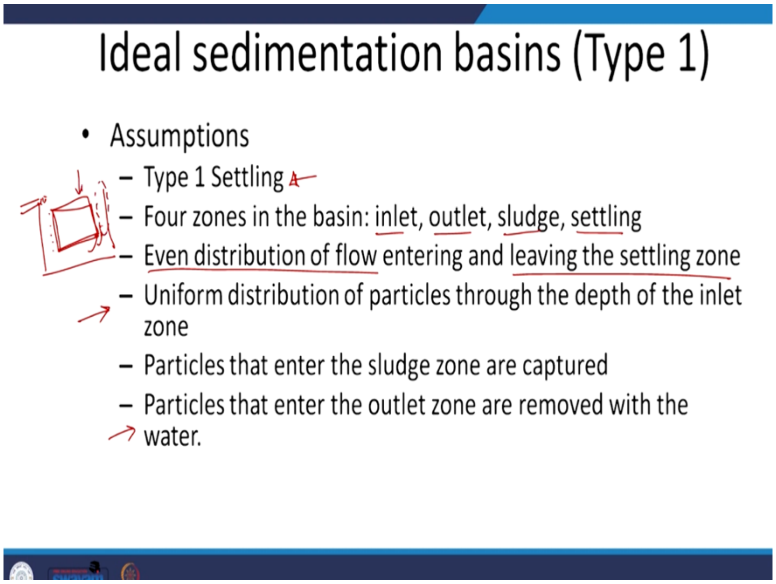

Ideal sedimentation basins (Type 1)

- Assumptions
  - Type 1 Settling
  - Four zones in the basin: inlet, outlet, sludge, settling
  - Even distribution of flow entering and leaving the settling zone
  - Uniform distribution of particles through the depth of the inlet zone
  - Particles that enter the sludge zone are captured
  - Particles that enter the outlet zone are removed with the water.

Let us move on. Ideal segmentation basins there are some assumptions. First thing is we are talking about type 1 that is why discrete and then as we looked at the relevant what we see video we have inlet zone, outlet zone, sludge and settling all these are general aspects. As I mentioned inlet zone we are going to try to achieve even distribution of flow. But that is not always possible and this outlet zone we are going to see again.

Even what we say distribution of flow when it is leaving the settling zone. But one aspect which we will look at later is that, we assume that the particles are uniformly distributed throughout the depth of the relevant tank. This is my tank and here is my flow rate and thus let us say is my settling zone. What I am saying is all these particles which are bunched together at the inlet are going to be uniformly distributed across this particular depth of the settling zone, depth of the inlet zone let us see.

Particles that enter the sludge zone are captured and are not scoured back up. Particles that enter the outlet zone are always removed, that something we need to look at or consider. Particles that enter this outlet zones as this is the settling zone and this is the outlet zone. If a particle is deemed to have entered here we assume that it is leaving the system.

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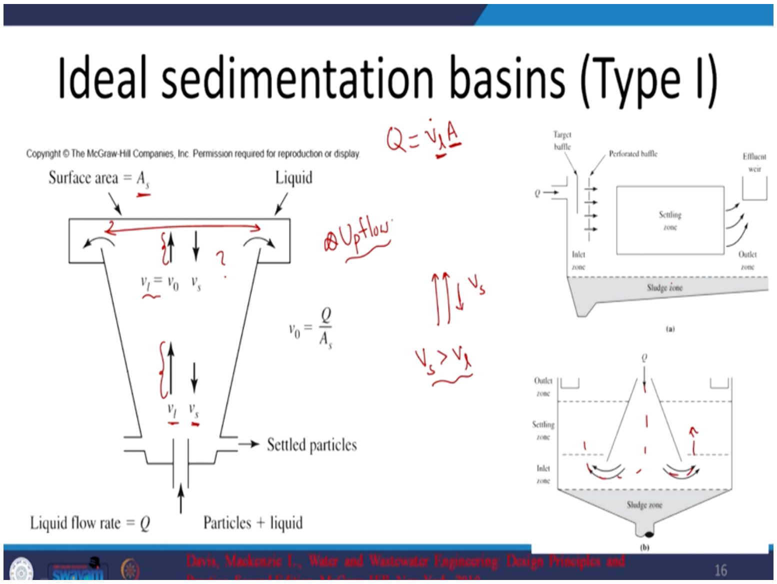

Ideal sedimentation basins (Type I)

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Davis, Mackenzie L., Water and Wastewater Engineering: Design Principles and

Let us look at the common types of sedimentation basins. Here we have up flow, so what do we have here fluid is coming up at this particular point and velocity of your particular liquid is given here. This is the settling velocity of your relevant particle which you will calculate from your Stokes law. Initially the velocity is higher here. But out here at the top I am increasing the surface area.

What will that lead to, I know that Q is equal to the velocity of that particular liquid into cross sectional area. For a smaller cross sectional area the velocity will be higher. But if I increase the relevant cross sectional area for the same flow rate what is going to happen the velocity is going to decrease, velocity of the relevant flow rate is going to decrease. That is what we see here it is relatively higher and here with the greater surface area.

The velocity of your particular fluid flow is going to decrease, let us see. Why is that necessary? Because if not, if the fluid flow is pretty fast and my settling velocity is this or relatively lesser. The particle will not be removed or will not be settling down. But the R net is going to be such that you know the particle is going to flow out with the relevant liquid. Only if my settling velocity is greater than this particular V l if I may call that out here.

V l will my particle be removed, so that is something to keep in mind. Let us see or let us look at some of the terms out here maybe I look at that later. We have different kinds of up flow. Then we have what we say rectangular sedimentation basins too. Let me discuss this in somewhat greater detail.

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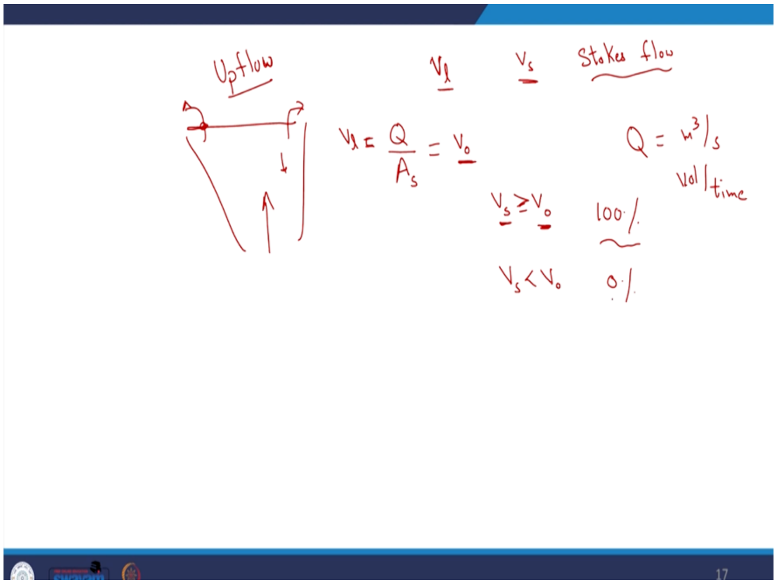

What do we have, we are talking about up flow sedimentation basins and what am I concerned with the velocity of flow of the liquid and the settling velocity of the particle which I will calculate from my Stokes law which we discussed earlier. Stokes law as we know is only valid for laminar flow conditions, that something to keep in mind. What is the velocity of this liquid going to be dependent upon.

It is going to be equal to what now the flow rate of the relevant liquid flow rate Q units can be meter cube per second or volume per time by the cross sectional area. Which cross sectional area am I concerned with, this surface area at the top. I am going to say that that is A s. What do you have this is nothing but the surface overflow rate that something for you to keep in mind. This is the surface overflow rate.

If my particle settling velocity is greater than or just equal to the surface overflow rate 100% of the particles will be removed. All those particles with a settling velocity greater than my surface overflow rate. This is the surface and the velocity at this particular point we are calling that to be the surface overflow rate. The flow is going in this direction because it is up flow.

If all those V_s having greater than or equal to or being greater than or equal to V_0, will be removed. Those particles with a settling velocity less than V_0 will not be removed. Everything or 100, 0% will be removed. Either its 100% or 0% removal though in practice it will not be the case, but theoretically that is what we see.

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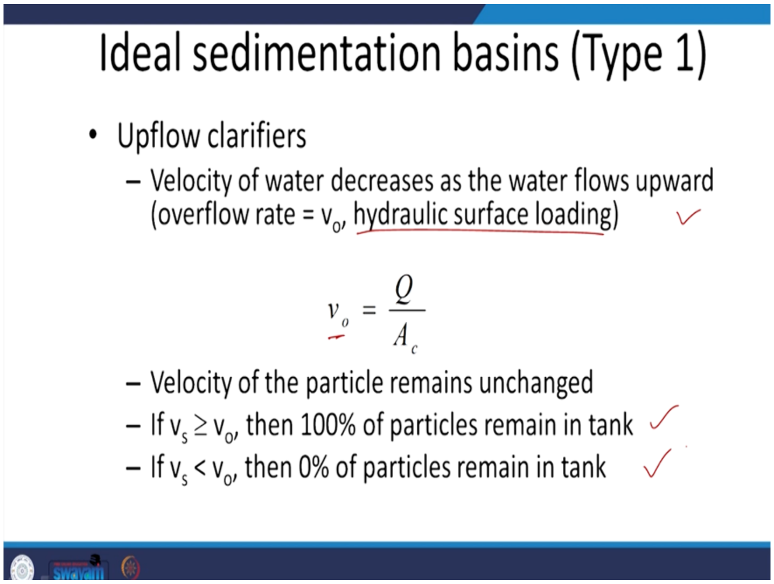

Ideal sedimentation basins (Type 1)

- Upflow clarifiers
  - Velocity of water decreases as the water flows upward (overflow rate = v_0, hydraulic surface loading) ✓

$$v_o = \frac{Q}{A_c}$$

  - Velocity of the particle remains unchanged
  - If $v_s \geq v_0$, then 100% of particles remain in tank ✓
  - If $v_s < v_0$, then 0% of particles remain in tank ✓

Let us see what we have up flow clarifiers that is what we just discussed and overflow rate or another term I should have mentioned earlier hydraulic as in water surface loading. Overflow rate or hydraulic surface loading and these aspects we just discussed let me move on. This is with respect to up flow.

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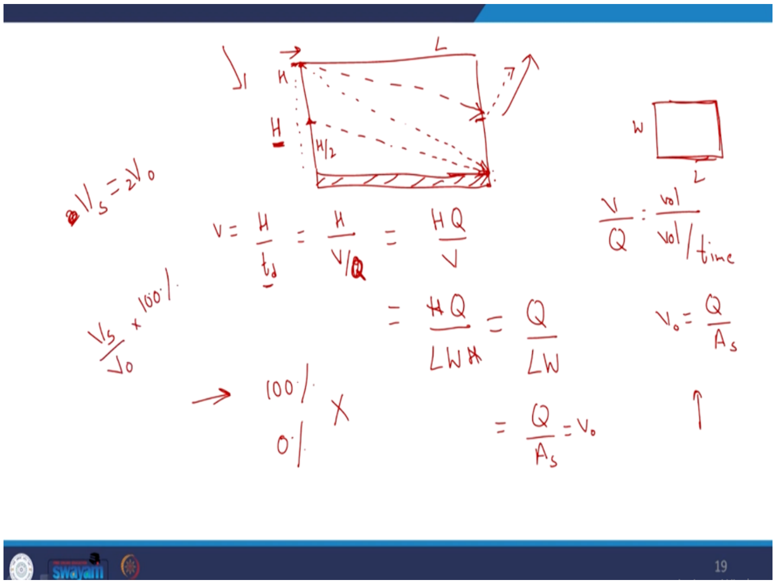

What was the second kind that we came across though? We came across the rectangular, what do, we see sedimentation basins are the flow in the horizontal direction let us see even for circular basins. There we are only concerned with the settling zone I am not concerned with the inlet zone I am not concerned with the outlet zone. But one aspect to remember is that all the particles we are assuming are uniformly distributed.

Any particle that is not within this sludge zone which is at the bottom and which leaves this settling zone even here is assumed to leave the relevant system. That is something to keep in mind. Let me what we see note down a few variables here. This height is H and length is L and if I look at the top view, this is the length and the width is this let us say.

My particle is coming in out here and the worst case scenario not worst if it is just about to be captured it can travel you know. It can even if it comes till here, we are assuming that it will be captured let us say. What is it that is available or what is it that needs, it needs to do the particle I mean. It needs to traverse a distance of H during the time that this particular water or particle stays in this particular tank.

That is what we have. Let us see you know what it is that it is dependent upon or such this velocity. Let us see H by time for detention, but what is H, I mean H is the height and what is this time of detention, how will I get that let us see. Time how can I get that let us say I know that Q is volume per time, let us see Q. If I say its V by Q volume by volume per time so I can get the relevant time.

I need to divide by V by Q, this is not theta it should be Q. That will be equal to H Q by volume. What is the volume going to be equal to let us look at it H into Q volume equal to length into width into height. What is going to cancel out, height and what are we going to end up with its Q by L W. That is what we have out here so as you see here, first aspect is that though it seems counter intuitive.

This velocity let us say that we are calculating out here which will give us an idea about the cut off for the relevant particles. It is again similar to the relevant surface overflow rate which we calculated for the up flow relevant up flow clarifiers. There too we had the surface overflow rate was Q by surface area and here too you see that this is nothing but Q by surface area. This is our what do we say surface overflow rate for the rectangular basins.

But unlike the case of the up flow clarifiers, up flow is where we have the flow up there. For the flow where we have I mean where the flow is horizontal. We are not going to just have 100% removal or 0% removal. This is not going to be the case. Why is that, because here the assumption is that all the particles are uniformly distributed across the height of this particular cross sectional area.

If a particle that comes out here with a settling velocity just equal to V_0 that will be removed. But if it comes out here let us say or with a lesser one, let us say I should have drawn a better figure or let us say we let us say it has to be such that V_s is V0 by 2 or 2 Vs is V_0 let us see and this particle is out here. This particle let us say is travelling at a V_s such that it will just be removed at this point.

But we see that it came in at H by 2. But what about the particle that comes in that H. That will not be removed right this parallel line as we can see that particular. What we say that particular particle which comes in at height H will not be removed as you can see it is going to leave right, so it is we are not going to have 100% or 0% removal. But we are going to have fractional removal.

That is going to be given by V_s by V_0 into 100% the percentage removal . That is something that we will have to look at.

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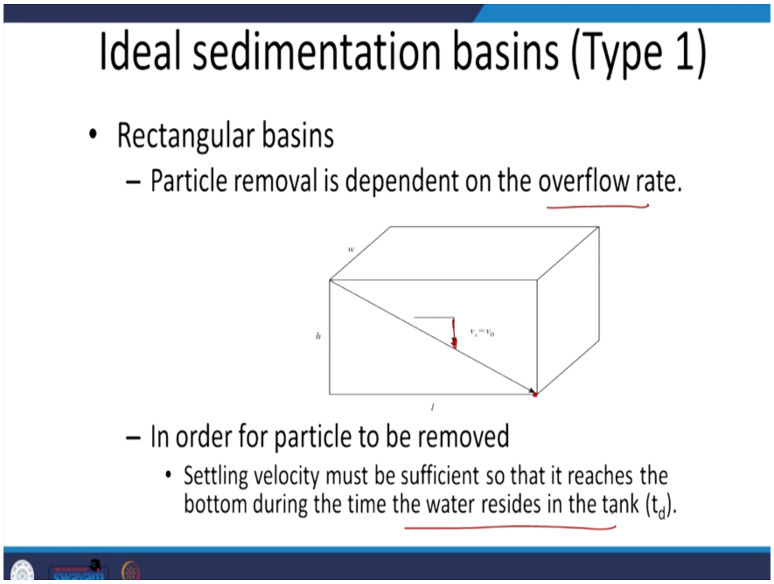

Ideal sedimentation basins (Type 1)

- Rectangular basins
  - Particle removal is dependent on the overflow rate.

  - In order for particle to be removed
    - Settling velocity must be sufficient so that it reaches the bottom during the time the water resides in the tank (t_d).

What do we have rectangular basins, particle removal is dependent on the overflow rate which we just looked at. Obviously as I mentioned or we mentioned settling velocity must be sufficient that such that it reaches the tank or the bottom or reaches this sludge zone during the time that the water resides in the tank.

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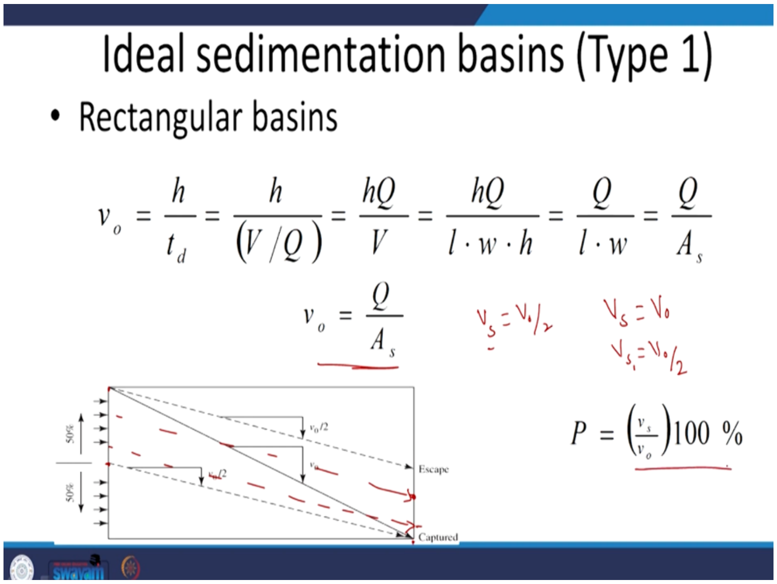

Ideal sedimentation basins (Type 1)

- Rectangular basins

$$v_o = \frac{h}{t_d} = \frac{h}{(V/Q)} = \frac{hQ}{V} = \frac{hQ}{l \cdot w \cdot h} = \frac{Q}{l \cdot w} = \frac{Q}{A_s}$$

$$v_o = \frac{Q}{A_s}$$

$V_s = V_0/2$

$V_s = V_0$

$V_{s_1} = V_0/2$

$$P = \left(\frac{v_s}{v_o}\right) 100\ \%$$

That is something that we looked at and what did we do we calculated this and we came up with our surface overflow rate. We looked at this particular case as in V_0 out here just captured.
And if the settling velocity is such that its V_s is equal to V_0 by two that is what I corrected earlier is not it. I should have written it the other way then . This is for the case where we were talking about H and H by 2.

$$P = \left(\frac{v_s}{v_0}\right) \times 100\%$$

Where the settling velocity is relatively lesser let us see. It is lesser such that earlier case we looked at V_s equal to V_0 and now we are saying V_s equal to V_0 by 2. What do we have if it comes in at H by 2 we see that it will be captured. But that fraction of the particle which is above it will not be captured. These flow paths are going to be like this so this is escape. That is why we will not have the 100% or 0 removal as discussed in the up flow clarifiers. But we are going to have a percentage removal and that is what we see out here.

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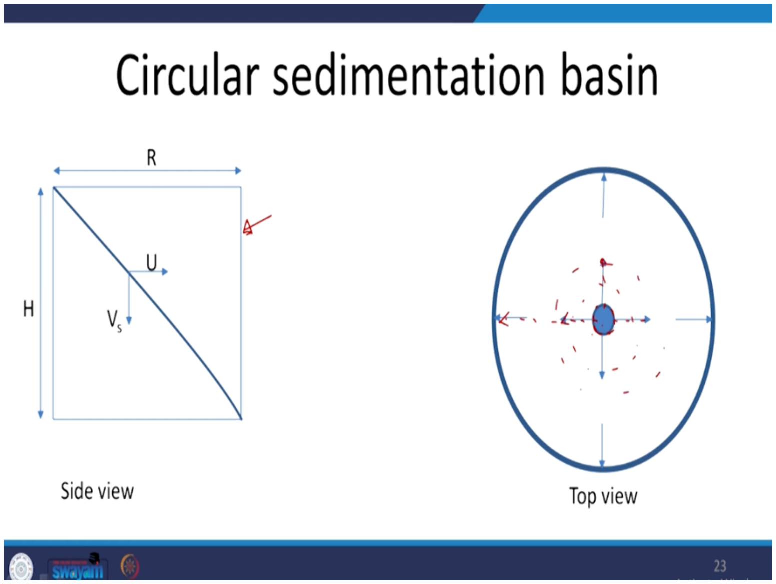

Circular sedimentation basin

Let us move on so circular sedimentation basin 2 what is it that we see. We see that it comes up in the center and then flows radially here again horizontal flow itself. Typically, if we look at the relevant design the rectangular basins make the best use of the relevant cross sectional area or the area available let us see. But what do we say circular basins are preferred, because relatively low maintenance with respect to the hopper system .

Relatively low cost, so thus people go for the relevant what is this circular segmentation basis. But if you are looking at the design and the effective use of the; what is it area, the rectangular basins are typically better. That is a no brainer if you can think of this what we have out here and the particle distribution radially let us say. That is something to keep in mind.

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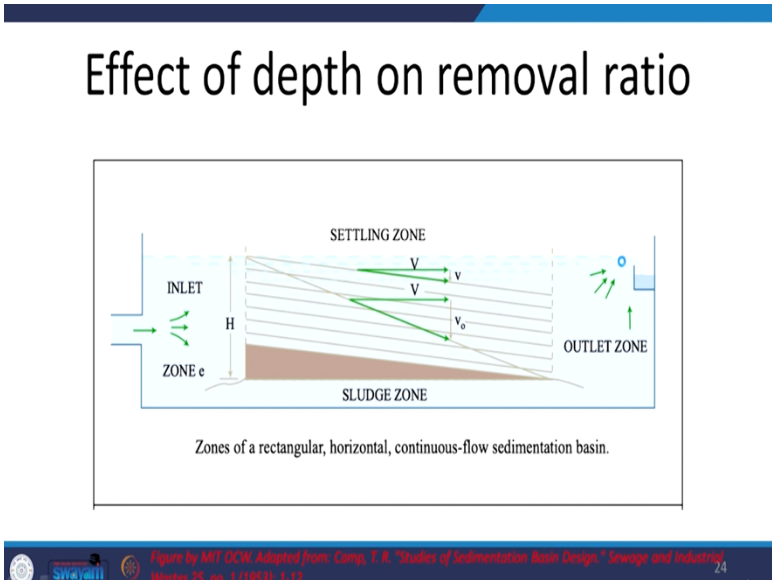

Effect of depth on removal ratio

Zones of a rectangular, horizontal, continuous-flow sedimentation basin.

Figure by MIT OCW. Adapted from: Camp, T. R. "Studies of Sedimentation Basin Design." Sewage and Industrial Wastes 25, no. 1 (1953): 1-12.

We are going to look at effect of depth on removal ratio but looks like I am almost out of time. We will discuss this in the next session but again we were looking at type one. You know in that context we saw that the critical aspect is the surface overflow rate both for your, up flow and for your rectangular basins. Thanking you for your patience I will end today's session.