Water and Waste Water Treatment
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Lecture - 39
Design of Flocculation

Hello everyone, welcome back to the latest lecture session. In the last couple of sessions, we were looking at coagulation and flocculation. In that context, we looked at gentle mixing for flocculation. You do not want to have turbulent conditions, because you are going to break up the floc and how do we understand this or quantify this level of mixing? We looked at the mean velocity gradient.

And we looked at capital G and that was equal to the square root of P / mu V, p being power and V being the volume, mu being the dynamic viscosity of the relevant fluid. , the greater viscosity for the same power, you are going to have less energy. So, we looked at these aspects and we looked at different kinds of impellers and based on the force friction force, yes, , how to calculate the energy dissipated?

Yes, from the energy dissipated or the power, , you can calculate the power required and you can calculate G as per the relevant variables. So, in this context, we started looking at a particular question.

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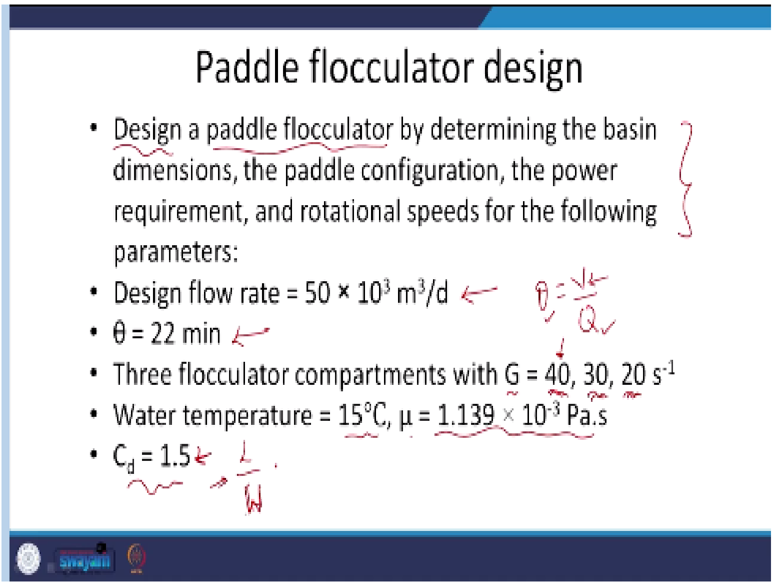

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We have or we were looking at this particular aspect we were designing a paddle flocculators. Paddle, what are we talking about? These are paddle flocculators. , we will have to look at the aspects such as the spacing between each; the width, the length, spacing between these and spacing from here to the wall, spacing from here to the bottom. These aspects you have to decide.

These general spacings relatively easy to do; you have thumb rules are relevant tables to guide you, but for the aspects related to the width and length and how many , it is 1, 2, 3 or such, you will have to look at the level of mixing that you want. And based on that, you will come up with the relevant , paddle boards. So, let us look at what we have, we have the design flow rate.

We have the retention time already given meaning, we know that theta is equal to V/ Q. So, from that , I can calculate V, because I already have theta and Q. So, there are 3 flocculator compartments with decreasing levels of mixing. And that is typical, you will never have one with a uniform level of mixing. So, in this session, we will only look at one , compartment and , you can design it for the other compartments.

Water temperature and thus, this temperature; the viscosity is given and coefficient of drag which will depend upon length to width ,. This will be in the relevant tables for a specific length to width ratio. So, viscosity, why is that important? More viscous (03:21) for a given power that you are applying , relatively lesser level of mixing or turbulence, .

So, because we know that this G is equal to square root of P / mu volume. So, if I increase the viscosity for the same power, G is going to decrease. So, that is something to keep in mind.

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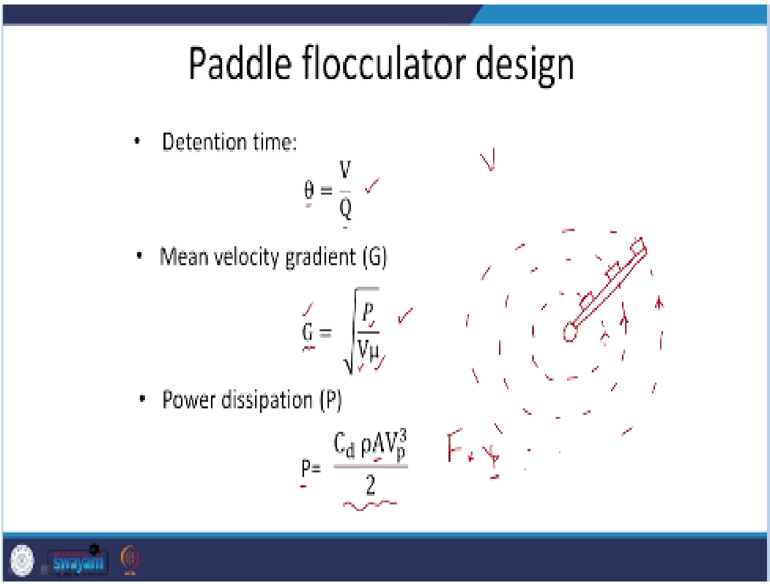

Let us look at the 3 formulas that we typically use. , dimension time, we covered this. Mean velocity gradient, yes, we already covered this. So, depending on the question, you will go from either the power to calculating G or from G to calculating power, . So, here, what is it that I am doing? First, I will, what is the approach? What is the overall approach? First, from the given theta and Q, I will calculate the volume.

Once I have the volume depending upon the G value, we know the G value; we know the viscosity; we know the volume; I will calculate the power that is required. So, either assuming 100% efficiency or lesser, I will calculate or take this P and use this. This is nothing but force into velocity. Velocity of that particular what is this, the blade, . So, that is how we have this and from here, I can calculate the cross sectional area and go ahead with it.

And even for calculating this velocity of that particular paddle, we know that if this is the shaft and this is my paddle holder, this is the side view maybe. So, I want this velocity. So, we looked at this velocity will be different depending on the relevant radius because within the same time, , once add the further locations with increasing or you are going to have greater velocity, .

, we will come back to that. So, that is the approach out here. And once we calculate the area, it is relatively great saving from there. Let us move on.

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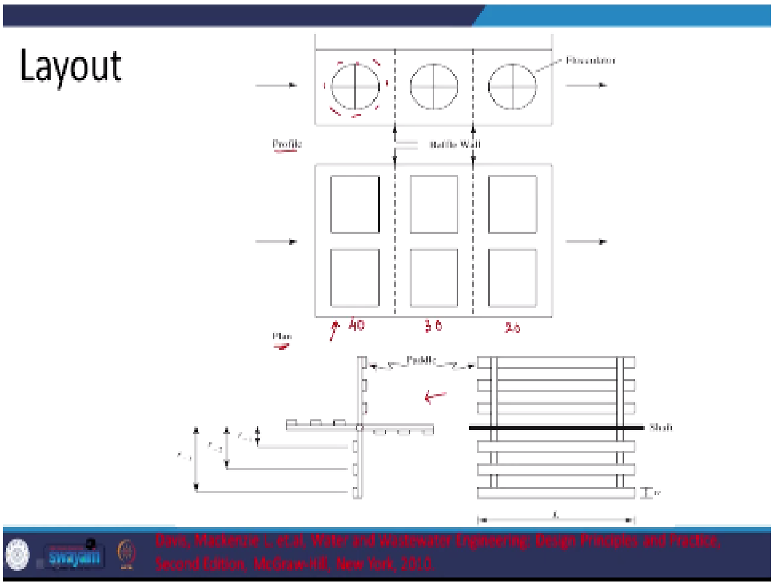

So, what is it that I am doing? Here, I am calculating or having to design this set of basins. So, here in this compartment, G is 40, then 30 and then 20. For Today, we are only going to look at this particular compartment. Now, I do not know whether it will be 2, 3 or 1 but , because I wanted to illustrate what we were doing before we got in, I wanted to put this figure. This is the top view the plant.

And from the side view,   this is what it looks like, you have the paddles flocculators and this figure, if we look at it, it is nothing but this. So, what do we have out here? We have 3 , paddles, yes, at different spacings . How do I get the information related to spacing? While we will look at this particular usual recommendations for a paddle wheel flocculator.

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Yes, with respect to the wheel, with respect to the paddle board , we also have the spacings given. So, these are general thumb rules which will be provided to you. So, that is not an issue and what else. So, different distance from the relevant centre, this will affect the velocity of that particular paddle that is something to keep in mind. Yes. So, and then the crease crucial aspects are length and width. Yes, length and width, because that will affect your level of mixing. Yes.

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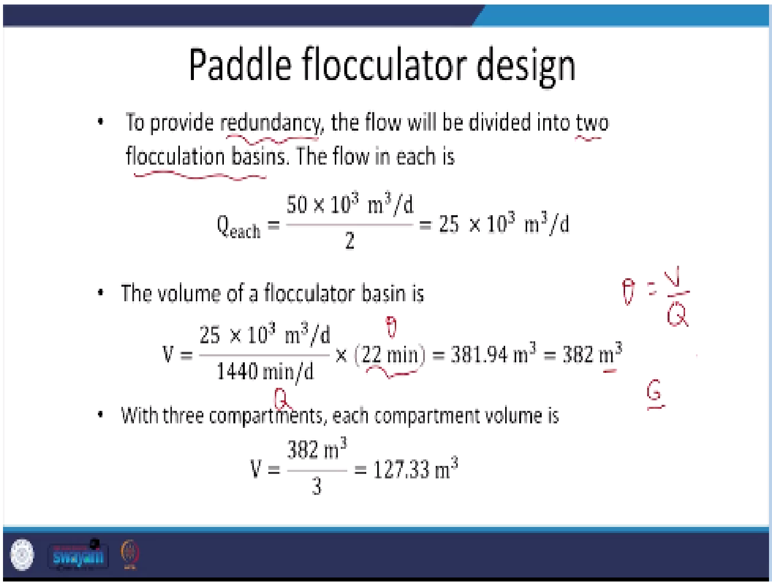

Paddle flocculator design, let us get to it. So, as we know, we were for redundancy, during downtime or maintenance or such, you are going to want a fallback option. So, that is why you will talk about 2 flocculation basins and the flow in each is half of what we have. So, if we go strictly by the guidelines, you have to design one for 50 each or each one for 50 into 10 Q metre cube per day, but here we are not doing that.

The volume of flocculator basin based on theta, volume, theta equal to V/Q, yes, and volume then equal to theta into Q. So, from that, this is theta (ɵ) and this is Q, and you can change the units around and looks like this is the volume that I want with 3 compartments, because each one this is the total volume keep that in mind. And we have 3 compartments because of different G values. So, 1/3 for the first compartment, so, the volume is 127 metre tube.

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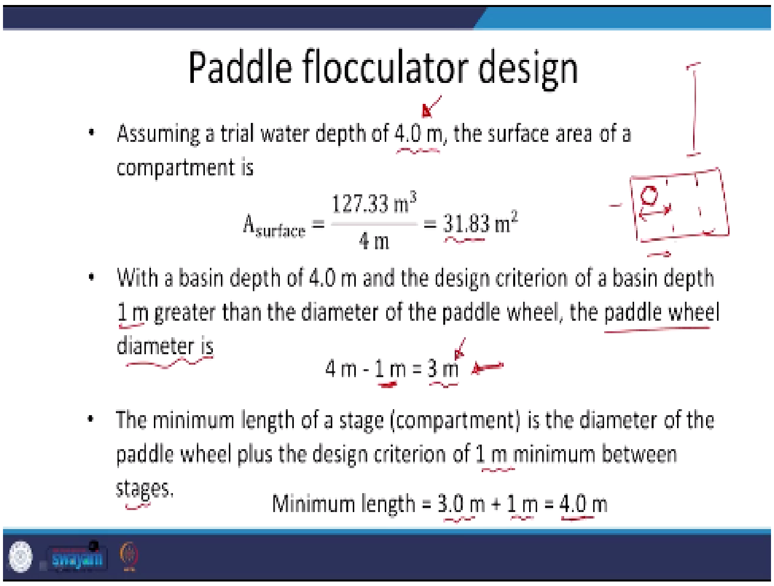

Let us move on. So, trial water depth, 4 metres, the surface area then will come out to be volume by depth that is going to be 31 metre square. Trial, typically decent value not too high and certainly not too low considering the paddle vet. Yes, with the basin of 4.0 metres and design criteria, which was presented in the table previously, of basin depth one metre greater than the diameter of the paddle wheel.

The paddle wheel diameter is , so, , I will get this. This information is from the table. And another way to go around it is, first look at the paddle wheel diameters or the diameters of the paddle wheels which are available to you. And then , look at the clearance and depth. , it depends upon also being able to find what you want. So, it cuts both ways, .

, here we are taking the other approach, where we assume everything is going to be available to us. The minimum length of a stage or a compartment, so, for example, let me draw this. So, this is the length, but keep in mind that there are 3 compartments. So, this is the length. So, the minimum length of a compartment is the diameter of the paddle wheel. So, here I am going to have paddle wheels. They are going to rotate out here.

So, we will be the diameter of the wheel plus the design criteria of one metre minimum between the stages. Yes, so, 3 and 1 metre, so, 4 metre. Why 3? We just found that this diameter is going to be 3 metres based on the aspects related to the depth and from that depth, we calculated the paddle wheel diameter and from that we calculated this length. From that, we calculated this length.

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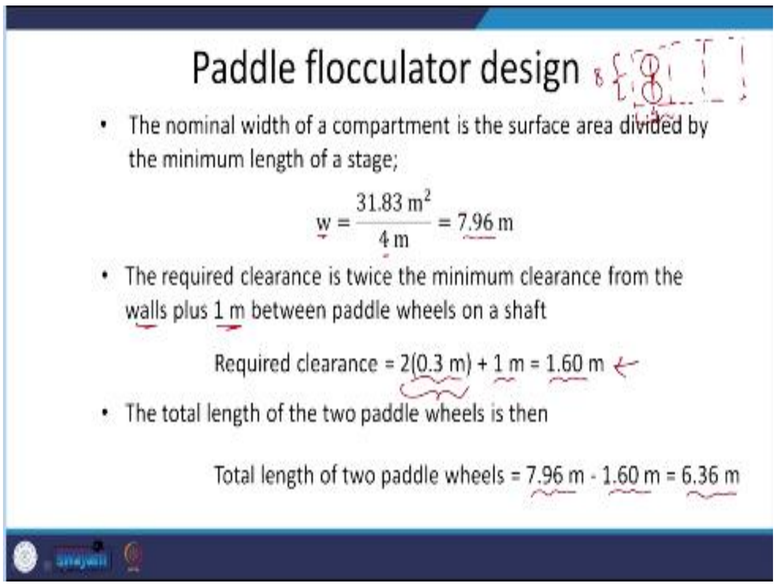

So, if we have the length, I can calculate the width from the area that we had earlier. Area by length, this is the width. So, what did I calculate? I just calculated the, so, this is my compartment, yes, so, this came to be 4 and this came to be almost 8 metres or 7.96 metres that is what we calculated and the required clearance is twice the minimum clearance from the walls plus 1 metre between paddle wheels on a shaft. There is some more to go.

So, required clearance is 2 into 0.3. , from the standard tables and 1 metre. So, it is 1.6. Required clearance is twice the minimum clearance from the walls. Twice the minimum clearance from the walls plus 1 metre between paddle wheels on a shaft. So, you have 2 paddle wheels . Yes, so, 1 metre between paddle wheels on a shaft. Total length of the 2 paddle wheels is then going to be 7.96 minus 1.6.

So, the total length of the 2 paddle wheels will be 6.36. Here, we also took into account; already took into account; the clearance and the spacing between these paddle wheels. , where did we get this set of information from the table? Yes.

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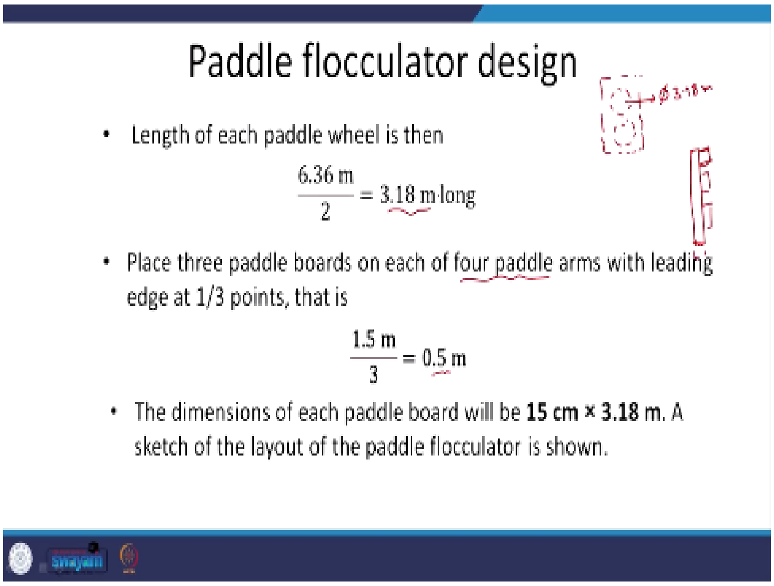

So, the length of each paddle will be 6.36 by 2. So, until now, what do we have? We have the width; we have the length; we know the clearances; we know that it is going to be 2 and each one is going to be, the diameter is going to be 3.18 metres, . At the length of each paddle wheel, there is depending on how you are going to mention it. So, place 3 paddle boards on each of 4 paddle arms.

So, here we are going to have 4 paddle arms that is something to keep in mind. With leading edge, add 1/3 points. So, , this is the paddle arm, leading edge is equal to , at 1/3 . Here, I did not draw it well. So, 1/3 the distance I think we will have the figure so that is 1.5/ 3, fine. So, that is 1.5 by 3, So, each one at 0.5. So, dimensions of each paddle board will be 15 centimetres into 3.18 metres long, . So, that is something to keep in mind.

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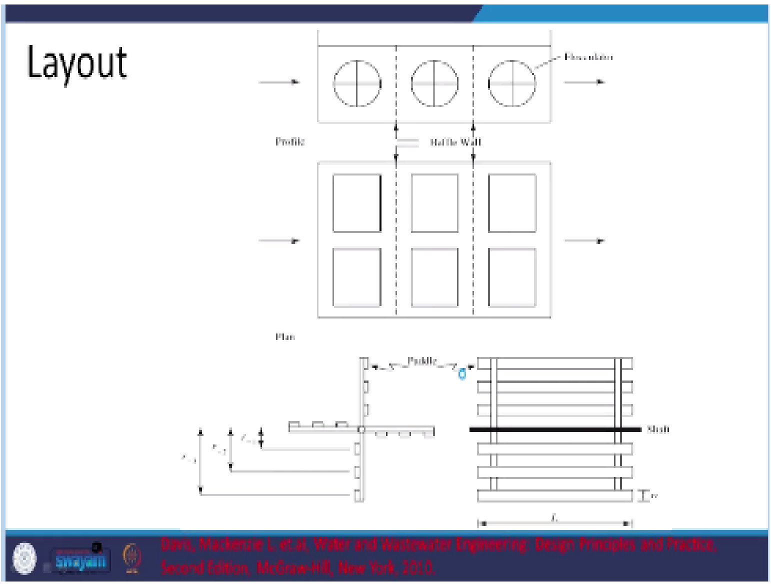

So, let us look at the sketch, this is what we already have. What is the length? The dimensions of each paddle board will be 15 centimetres into 3.18 metres long and the spacing will be this. So, let us move on.

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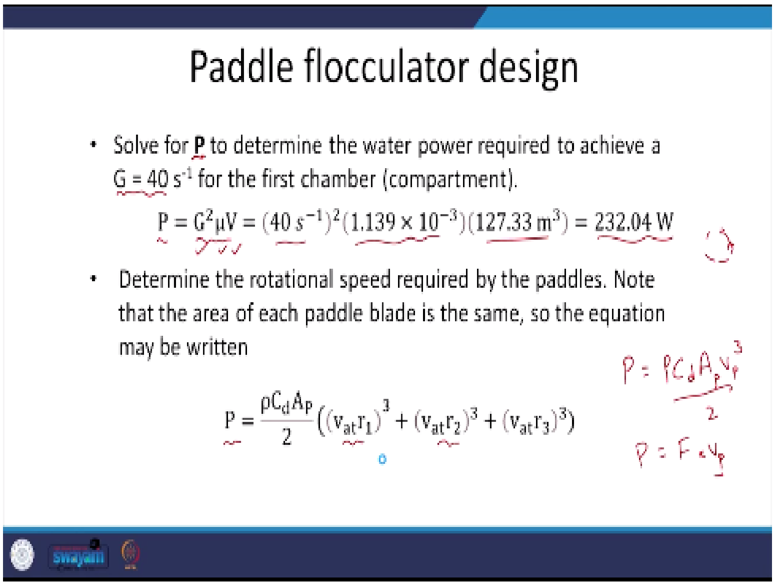

We are done with some aspects. Then we will check the design the different way. Solve for P now. I need to know the power from the G that is given . What it is? P = $G^2\mu V$. I have G; I have mu; I have V. V is the volume of that compartment. G is the mean velocity gradient, I know that it is 40 for the first compartment and mu dynamic viscosity. So, this is the power required.

So, now from this, I need to be able to calculate the rotational speed. The speed at which it is rotating the paddles rotation speed . So, here we are taking a slightly different approach based on the relevant clearances and the diameter or the spacing available, we calculated the area of each paddle and from that we are going to use to calculate the velocity. So, depending on information available, you will take one approach or the other.

So, here we have the power. For example, earlier we saw this particular equation. Power is equal to coefficient of drag, area of the paddle and velocity of the parallel cube by 2. This is nothing but power equal to that force, frictional force, , into velocity of the paddle. But here, there are different paddles, 3 paddles. There are 3 paddles as you can see, each one at a different distance from the centre and as we saw each one will have its own velocity.

So, I am going to look at all 3 of them and sum them up. So, that is what we have here and substituting for the velocity term.

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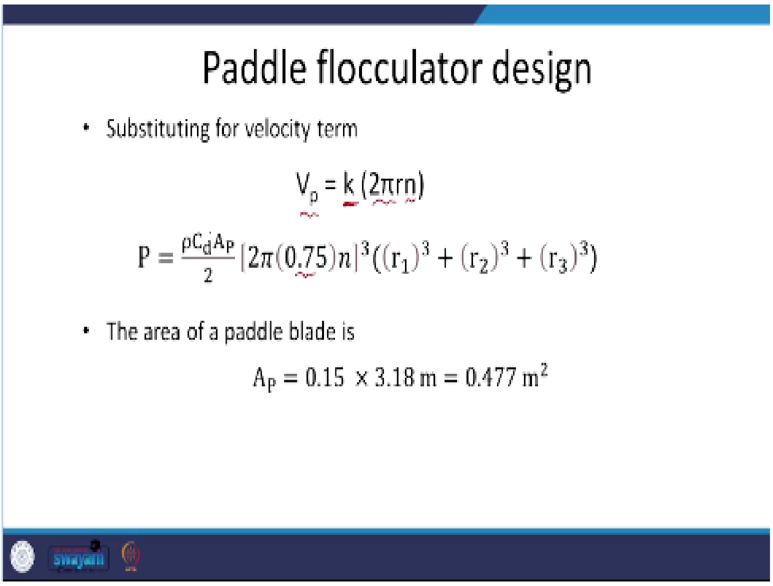

So, velocity of the particle, this particular constant 2 π r; the perimeter it is going to cover and rotational speed. So, the constant we are taking, is 0.75. This will give me an idea about the velocity of I mean, the paddle relevant to the water by relevant to the fixed coordinate.

So, that is something to keep in mind. In general , we are taking it 0.75 and then we are taking it out to be common.

So, area of the paddle , everything else is known except this. Area of the paddle. We already have area of the paddle. Yes.

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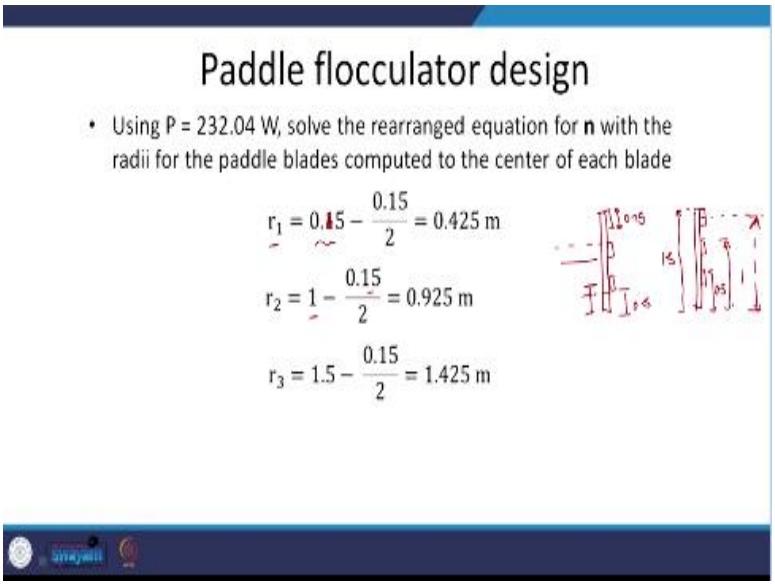

And using power, we already have the power and radius, we can calculate r 1, r 2 and r 3. So, this is based on the fact that we have at that 0.5 metre spacing, . So, 0.15 minus of this should have been 0.5 pardon me, -0.15/ 2 if I am not wrong, yes. And 1-0.15/ 2, 1 minus 0.15. Why 0.15? Because, this width of each is 0.15 and this one is point, , this leading edge was supposed to be 0.5, this was 0.5, this leading edge or , this should have been the leading edge, let me redraw that.

I have 3 here such that the leading edge , this is what they are calling as the leading edge, this is 1.5. And this is 1 and this is 0.5. And because, the width of each is 0.15, So, 0.15/ 2 will give me this particular distance, 1.5 , -0.15/ 2. So, that is what we have here. So, that is what we have here.

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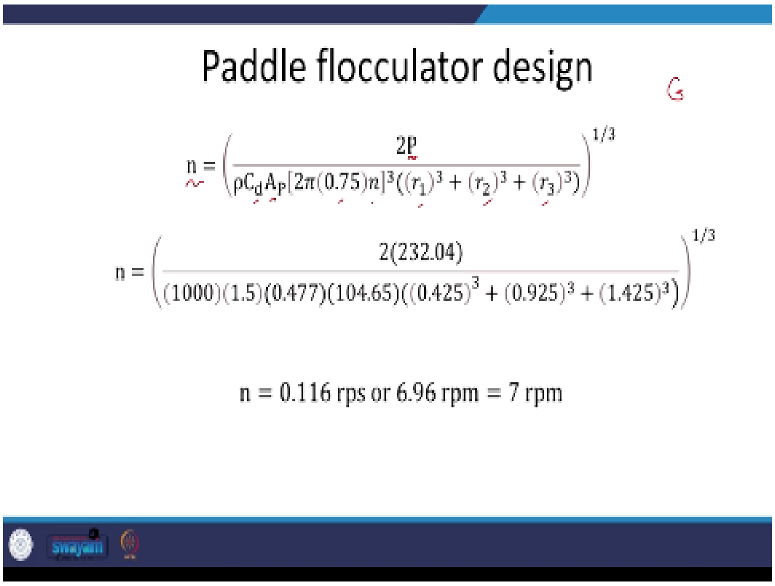

So, this is the radius we are looking at and from that, I will get the n or the rotational speed that I have to maintain. Power, we calculated that from the G that we required, yes, area of the paddle from the length and width, coefficient of drag given and then k 0.7 and rotational speed, we have to calculate r 1, r 2, r 3; we calculated. So, from that you solve for n. So, it comes out to be these many revolutions per second or 7 revolutions per minute.

, you can understand that it is not very fast , because in a flocculation tank, you want the mixing to be relatively gentle.

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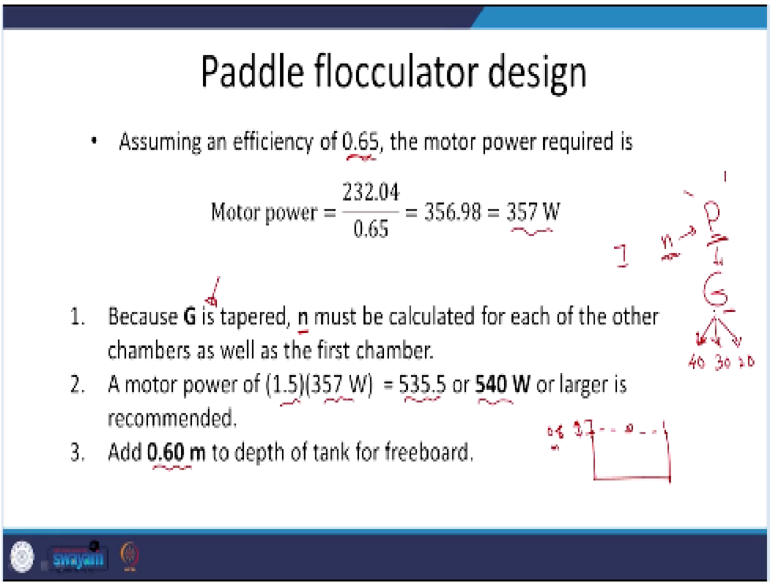

So, let us move on. Assuming an efficiency of 0.65. This is what we assumed as not all the power from the motor is going to be transferred to the water while the paddles. So, here we are assuming that the efficiency is 0.5. So, motor power required is the relevant aspect.

Because G is tapered and n must be calculated for each of the other chambers. Yes, this is one aspect. What has to be noted is how did we calculate and in that, we can use power, but the power will depend upon the G value.

The power will depend upon the G value but G value is different for different compartments. So, here for the first one relatively higher revolutions per minute 7 for a G value of 40. So, for a G value of 30 and 22, , the relevant revolutions per minute will have to be calculated and motor power of 1.5 into 357 watts which is 553, 540 watts or larger is recommended, .

Add 0.6 metres of depth of tank for freeboard the depth we took was 4 metres, we will never want water to be at the top level. So, we are flush with the top of the tank. So, you are going to have the water level here and this is the freeboard and this freeboard is 0.6 metres. the NPTEL kind of exam , we will not ask such an exercise which is maybe pointless, but given the relevant power or given relevant G value, you will need to be able to calculate the for a given set of data the revolutions per minute or such, .

But in general, you can understand that it is depend upon the clearances and the sizes of the paddles available. And also we have the 3 fundamental formula for theta for G and the power in terms of velocity of the particle, . So, these aspects, we consider and use them.

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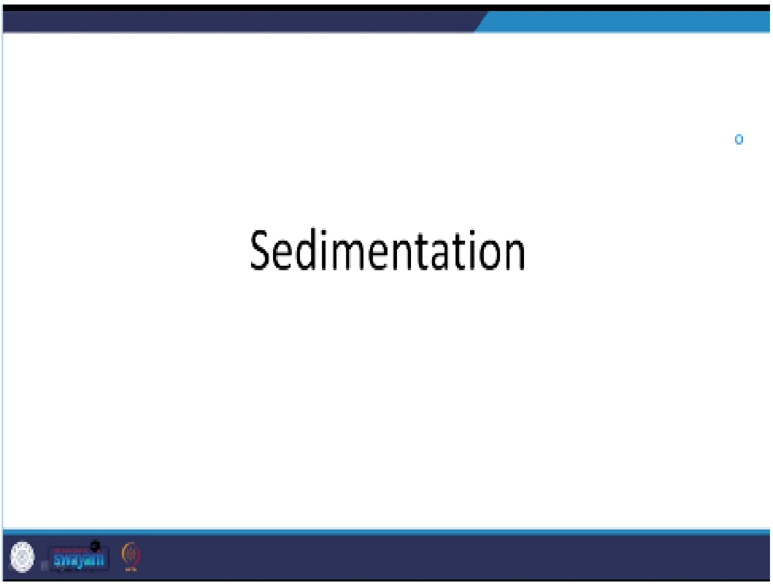

So, we are done with flocculation. I have destabilised the particles during coagulation and then what do I do now? I see to it that the conditions are such that the flocs are formed, flocculation is also done. So, what next? I will now let or give enough time for my friend gravity to see to it that these bigger particles settle down coagulation and flocculation. So, , sedimentation now.

Segmentation, we already discussed this, at least the principle in relative detail in the context of wastewater treatment. So, here we will only touch upon that briefly. So, let us move on and look at it here.

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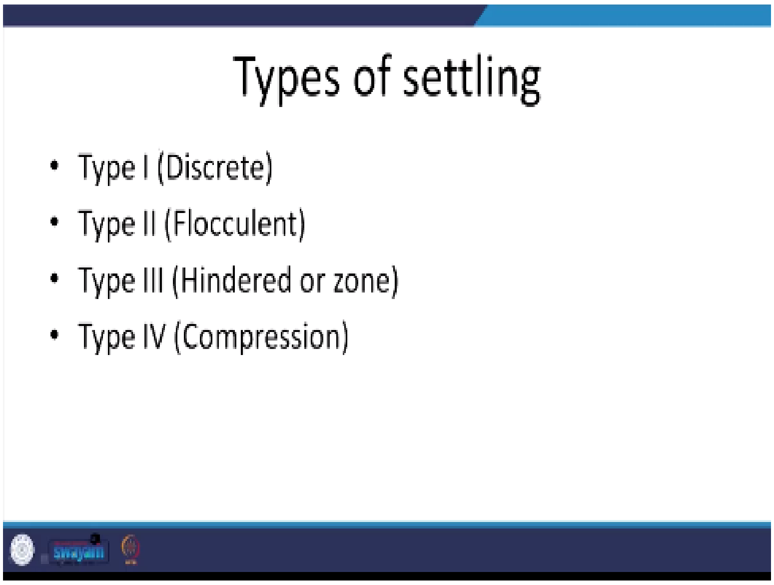

So, as we know, there are different types discrete, flocculent, hindered and compression. So, rarely will we see discrete.

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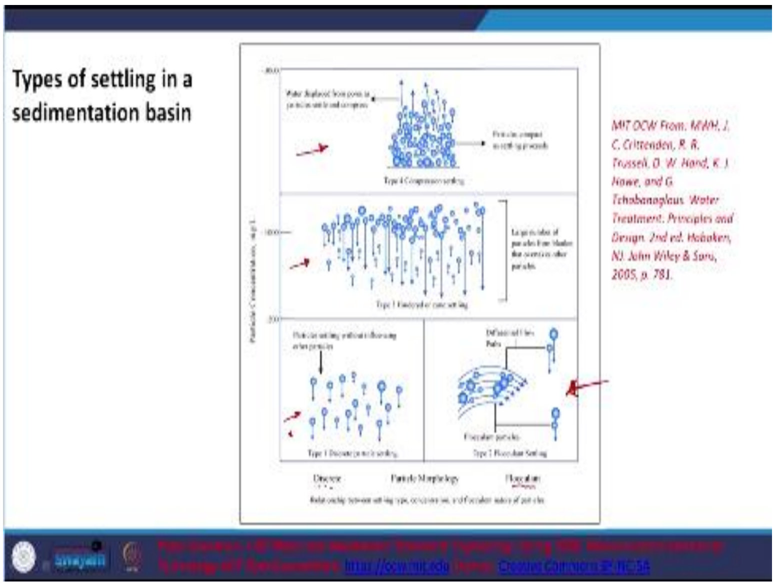

Let me see if we have the figure from MIT courseware. Yes, we have that. So, this is discrete. You can look at the particle sizes, , our particle concentration, pardon me, where it is relevant or under which concentrations it is going to happen. So, here it is discrete. Discrete meaning each particle behaves independently of the other, but this will happen very rarely. This is the ideal case.

In general, you will have the flocculent settling, where due to differential velocities of the water or different velocities of your particular particle, they are going to form flocs and you are going to have flocculent settling and this is what we will see in our sedimentation tanks for our water treatment atleast (20:00). In the context of waste water treatment , with respect to sludge settling or such we know that hindered or zone settling and then at the bottom, it is going to be compression setting.

But , in general for our water treatment relevant aspects, the sedimentation will typically be the flocculent or type 2 settling, .

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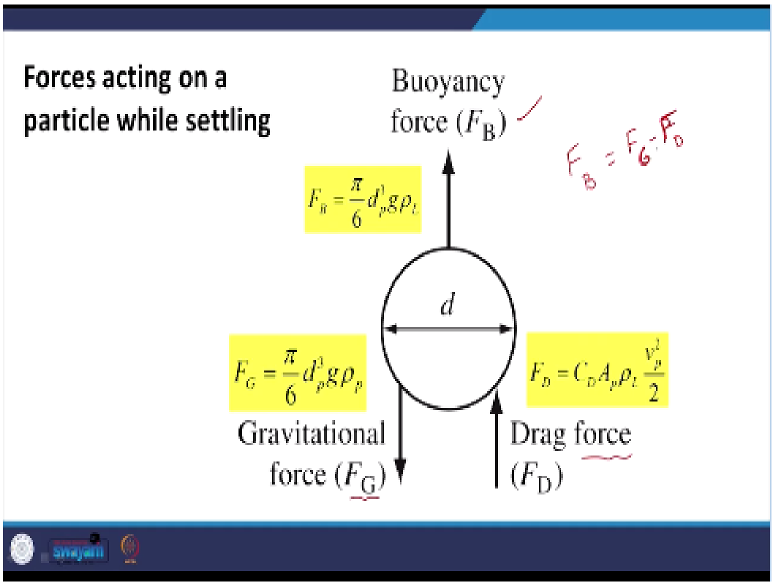

And just a quick recap of what or where we were or how we came about that. In general sedimentation, what are we talking about, , we have a tank. What is the role of the tank? We are providing enough time for our particular particle, which is flowing along with the water. So, water is flowing in this way and talking about horizontal flow, what is flowing in this way.

So, by the time, it reaches out or moves out, it meaning the water moves out of my settling zone, the particle should have settled down. So, we have a particular velocity of settling and we have the height of or the depth of our settling tank and our particles should cover this vertical distance or the depth, based on which aspect will it be governed. It will be governed by the settling velocity.

Settling velocity , how is it coming into picture? Well, gravity is always our friend, which always is with us. So, that on any particle, gravity pulls us down. And for particle in water, you will have buoyancy. And if it is moved down, , you will have the frictional force or the drag force, . These what can I say,

$F_B = F_G - F_D$.

So, that is when it is the particle is not accelerating anymore, you will have the terminal settling velocity that is when you will have the settling velocity. So, from here, you will calculate the settling velocity.

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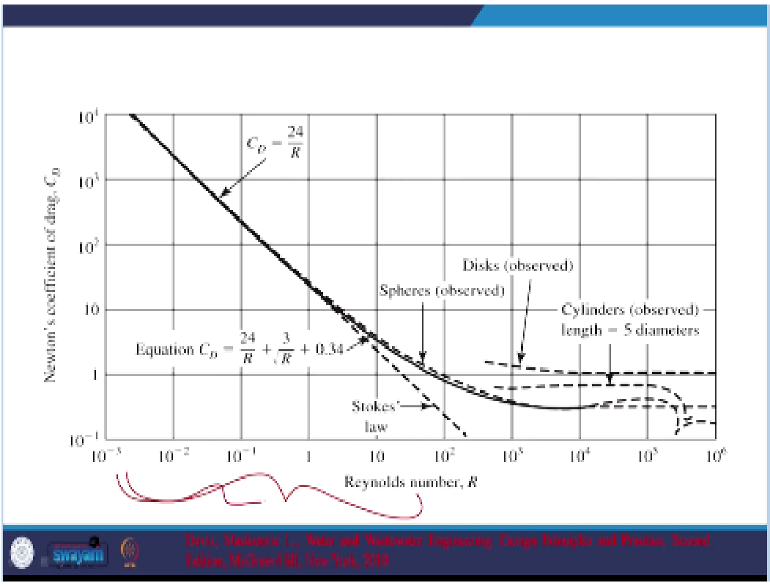

And it also depends upon the type of flow conditions. Yes. So, typically, Reynolds number one or less, what do we call that, we call that laminar flow conditions. And for laminar flow conditions, first spheres, stokes law is applicable.

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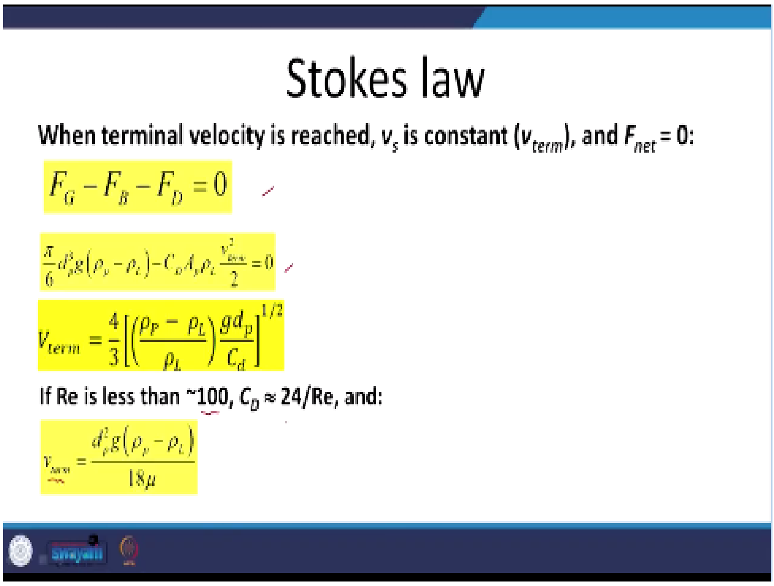

So, we can balance them out, put in the relevant terms and get the relevant, , equation and for terminal velocity, this is the equation, . , this is first spheres and we are assuming that the conditions are laminar flow. So, that is why we are saying that Reynolds number less than 1. And as you can see, coefficient of drag will also depend upon the relevant flow conditions. Yes. So, that is what we see, let us move on.

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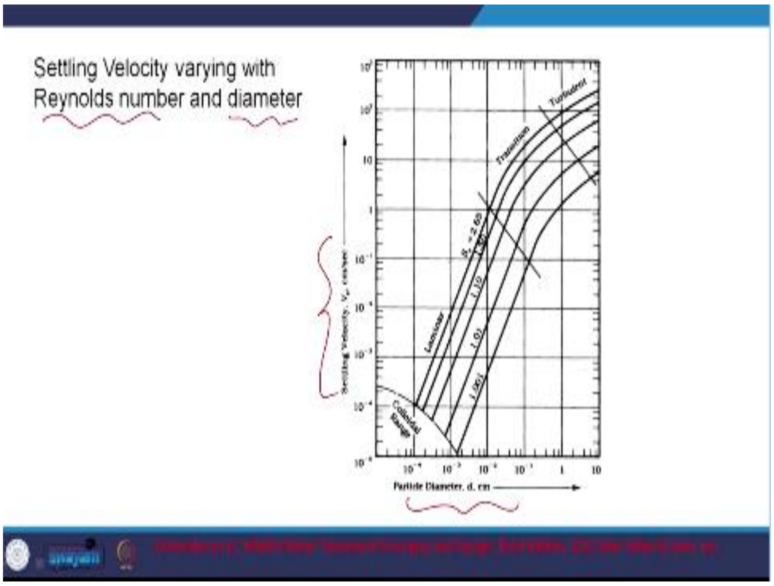

And settling velocity will vary with both the Reynolds number and the diameter . So, here we see that for our particles of interest, which are relatively lesser, they will settle under laminar flow conditions. And you can see that , because the size is lesser, their settling velocity is also relatively small. And , with specific gravity, this is specific gravity. So, heavier particles will settle faster that is something that you can see out here.

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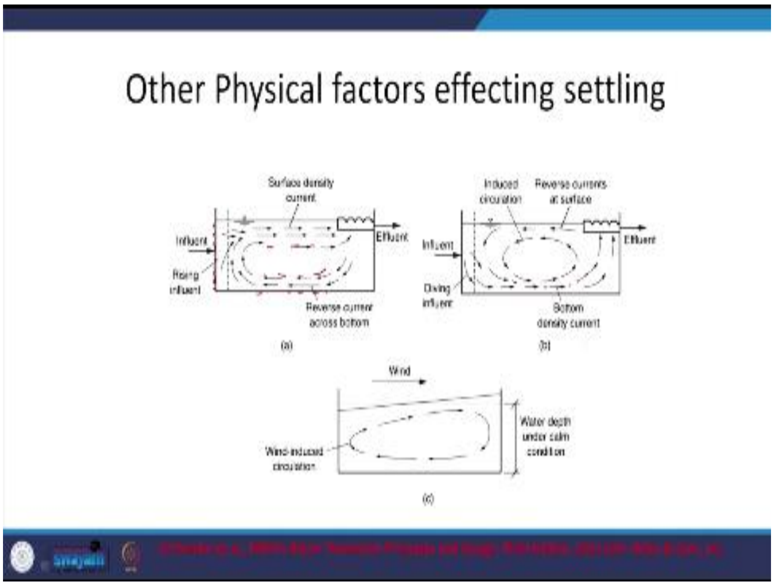

And one aspect with what we say, practical aspect with sedimentation tanks is that you will have to see it that the influent or the way that the water comes in, the energy should be dissipated relatively well. And when the influent enters this particular tank and to avoid, , aspects or issues such as these, what are these? So, you have rising influent, rising influent and that is why it is causing a particular reverse current here.

You are seeing this reverse current. Why is this an issue? So, whatever has settled down out here is going to be scoured up. Yes. And you are not going to have an ideal settling zone. And here , you have a diving influent. , you are going to have scoured up here. And this seen in windy conditions, you have wind that is creating this circulation inside the tank. All this you do not want to have that .

You want to have laminar flow conditions. So, , I am almost out of time. I will end today’s session and in the next session, we will continue talking about the sedimentation tanks and maybe briefly talk about the surface or flow rate and relevant aspects. With that, thank you for your patience. I will end today’s session.