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NPTEL ONLINE CERTIFICATION COURSE

Unit Operations of Particulate Matter

Lec-03
Sedimentation and Design of Thickener (Part-02)

Dr. Shabina Khanam
Department of Chemical Engineering
Indian Institute of technology Roorkee

Welcome to the third lecture of week 1 which is on design of thickener. This if you remember this section here we are considering one session where lecture 2 and 3 are clubbed in lecture 2 we have discussed the, we have defined the sedimentation, we have seen its application, and we have derived equation to calculate the cross sectional area of the thickener. Now in this particular section we will start the calculation of height of the thickener.

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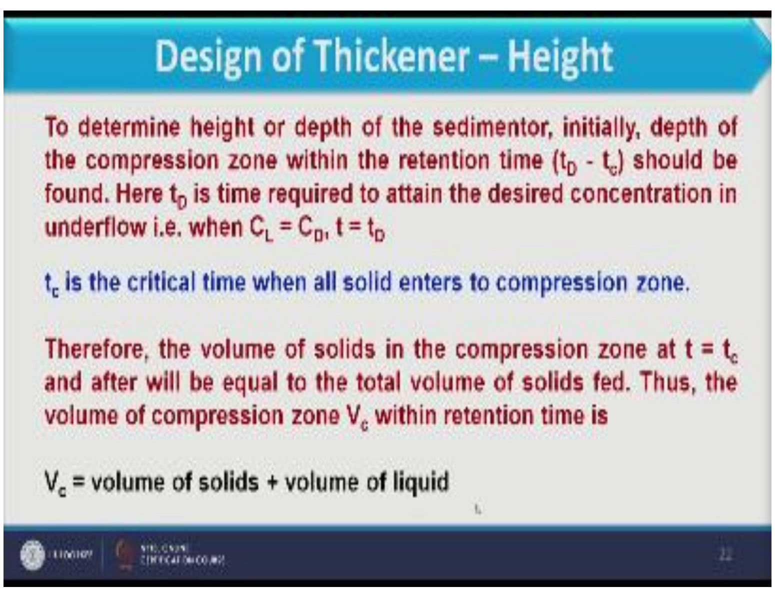

So to determine height or depth of the sedimentor initially depth of the compression zone within the retention time t_D-t_C should be found. Now here if you consider this t_D as well as t_C what is t_D is the, if you remember D we have denoted for the underflow, so time at which the concentration of underflow that is C_D is obtained that time is called as t_D. Now what is t_C is the critical sedimentation time which we have defined as where layer two layers will be, only two layer will appear that is clear liquid as well as the compression zone, clear liquid zone as well as compression zone.

So t_D is the time required to attain the desired concentration in the underflow when $C_L=C_D$ at $t=t_D$, t_C is the critical time when all solid enters to the compression zone. Therefore, the volume of the solid in the compression zone at time $t=t_C$ and after will be equal to the total volume of the solids fed. Thus, the volume of the compression zone within the retention time is volume of the compression zone is volume of the solid plus volume of the liquid available in the compression zone.

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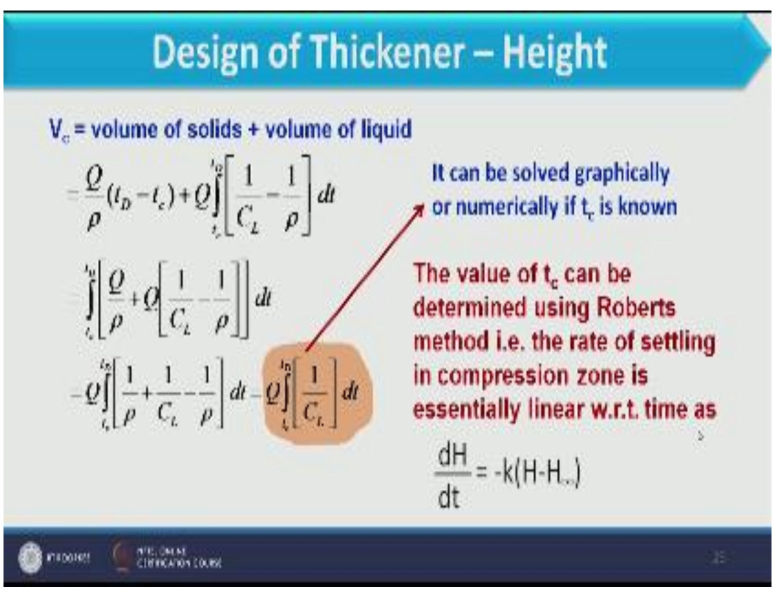

So how we can correlate this is Q volume of the solid is $Q/\rho(t_D-t_C)$ what is t_D-t_C is that we have seen the total time from critical to final concentration achieved and Q is the total fed, because all solids are entered into the compression zone therefore, we have considered total Q/ρ. So that is nothing but the volume of the solid and that is multiplied with time because Q is containing the time factor also plus Q integration t_C to $t_D[1/C_L-1/\rho]dt$.

Now what is this particular section Q is the total volume total mass flow rate of the feet $1/C_L - 1/\rho$ now if we multiply this by C_L so this would become 1 and $- C_L/\rho$ now this C_L/ρ is basically the concentration of solid divided by the density of solid so that's I nothing but the fraction of solid available in the compression zone.

So 1- that fraction of solid is available is equal to the fraction of liquid available in the compression zone so that we have multiplied with Q and dt after resolving this we can find this particular equation resolving this we can get Q t_c/t_d $1/\rho + 1/CL - 1/\rho\ d_t\ 1/\rho$ will be cancelled out so final equation would be Q integration form tc to td 1/ CL td, now this particular equation it can be solved graphically or numerically if tc is known so as I already know the td value I can calculate td value because I know the final concentration but I do not know the tc value.

So how tc will be calculated it will be calculated by the method proposed by Robert so this method shows the rate of settling in the compression zone is essentially linear with respect to time so the expression should be $dH/dt = -k(H-H)_{\infty}\ H_{\infty}$ y we have considered because that is the final height of the compression zone and H is the variable height of the compression zone.

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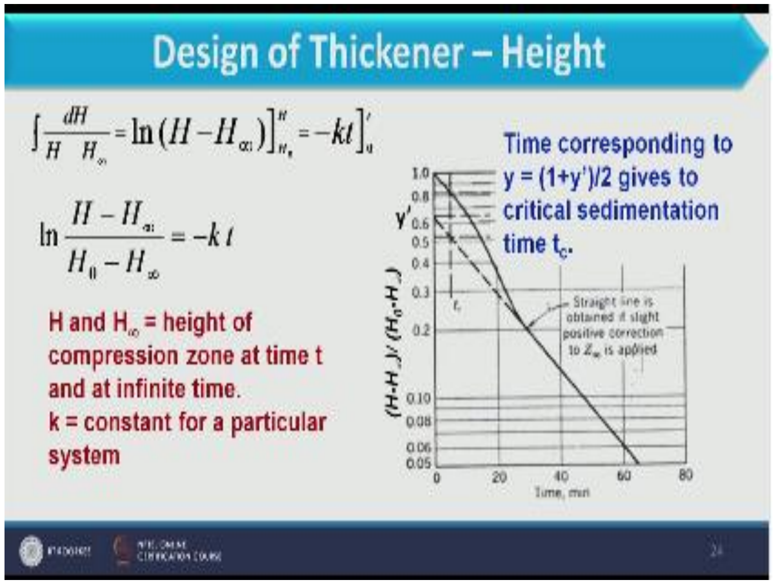

So here we have this expression after integration integrating this so $H-H_\infty$ / $H_0 - H_\infty$ log of this would be equal to – k t where H and H_0 is the height of compression zone at time t and at ∞ infinite time that is the final height of the concern compression zone so once we draw this $H-H_\infty$ / $H_0 - H_\infty$ verse t is semi log graph paper from the slope we can find the k value.

So this type of curve will apparel and here where you see at y axis would be semi log and x axis will be the normal graph so how we calculate the value of tc is the time corresponding to y which is equal to 1+ y' / 2 gives the critical sedimentation time now what is y' y' is as this particular section is almost liner as time passes it is almost linear so that is the compression own line when we extend this it will cut over here that would be nothing but the y' so 1+ y ' /2 some where it will lie over here and when we see the corresponding value of time the value we can see as t_c so this is the Robert Smith method to calculate the critical sedimentation time now if value of.

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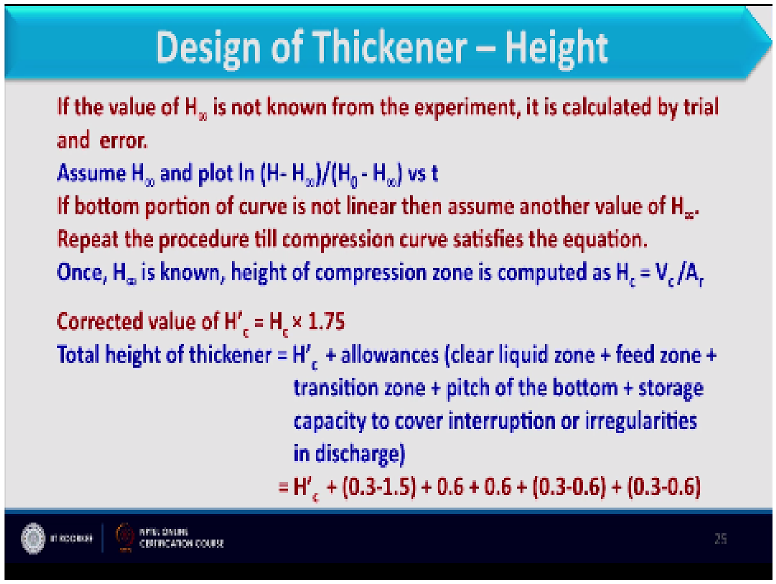

Now I value of h_∞ is not known from experiment it can be calculated by trial in error usually h_∞ we find through bad sedimentation test but if it is not available we have to go for trail in error what we have to do in this case we have to assume h_∞ and plot log H' H_∞/H_0 ' H_∞ verses time if bottom portion of the curve is linear then assume the value of H_∞ is correct otherwise we have to take the new value of H_∞ and fine draw the this semi log graph and observe the tail of this that should be linear.

If it is when it will come to the linear we have to consider that H_∞ value as correct value so once H_∞ is known the height of compression zone is calculated as H_c which is equal to V_c/A_r that is the volumetric volume on the compressions divided by cross sectional area so corrected height of the tank is H_c' that is which is equal to H_c x 1.75 1.75 is the correction factor here we have to calculate the total height of the thickener that is Hc' + a lines, a lines for what the clear liquid zone + feed zone.

Plus transition zone plus pitch of the bottom plus a storage capacity to cover interruption or irregularity in discharge so considering all these factors we have to calculate the height of the column height of the sedimentary and these co values are shown over here which a some of the values are in range and other values are a specific value so adding all these to H_c' we can calculate total height of the sedimentary now here we have illustrated design.

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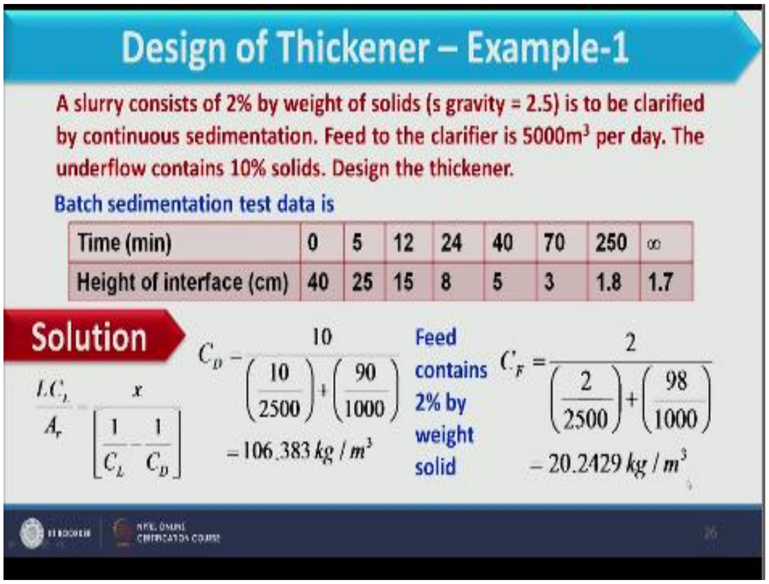

Of the thickener through an example here a slurry consists of 2% by weight of solid which is having a specific gravity 2.5 is to be clarified by continuous sedimentation feed to the clarify is 5000m^3 per day the under flow contains 10% solid for this system we have to design the thickener now for this system the bad sedimentation test data is available in this stable you can see here we have time as well as height of interface see this data is available to us. Now as far as solution is concerned this is the final; equation we have to find now what is the purpose of this equation we have to calculate A_r that is the cross sectional area of the tank through which we can calculate the diameter so here we have to calculate XCL and CD, as final concentration is 10% like underflow has 10% solid.

So final concentration we can calculate as if 10% solid is available obviously 90% water will be available so 10/10/2500 + 90/1000 so considering this we can calculate CD as 106.38, feet contains 2% by weight of solid so from here we can calculate CF that is 2% if solid is available 98% would be liquid so considering this expression 20.2429 would be the concentration of feet.

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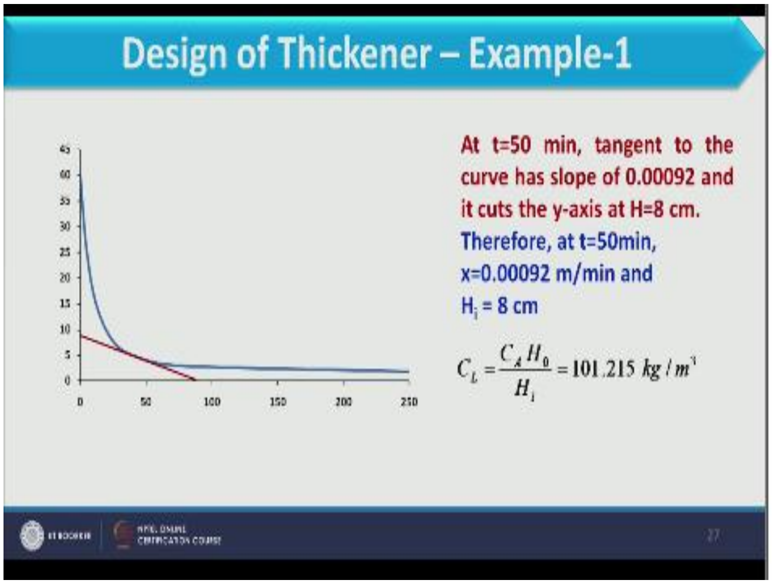

Now using batch sedimentation data we can draw this graph here y-axis is basically H and X-axis the time value now for example at some point we have to draw the tangent so to for that purpose if I am considering value 50 at t = 5o million tangent to the curve has the slope this tangent has that slope 0.00092 and it cuts the y-axis at H = 8 cm therefore the parameter should be at t = 50 x that is the sedimentation rate which is equal to 0.00092 m/min and HI in that case would be 8, so you can see the expression to how to calculate CL is H_i C_L = C_A H_0 this was the expression. So for this particular case we can calculate C_{LA} as 101.215 kg/m^3 .

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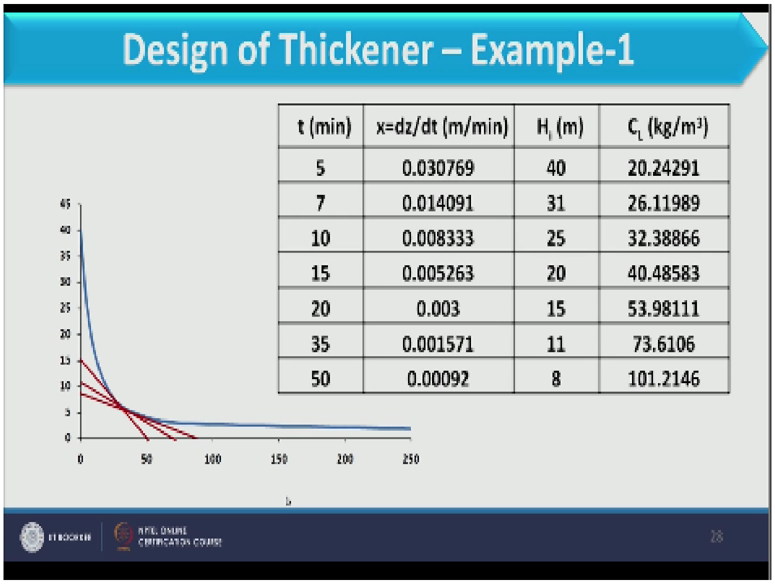

t (min)	x=dz/dt (m/min)	H_i (m)	C_L (kg/m^3)
5	0.030769	40	20.24291
7	0.014091	31	26.11989
10	0.008333	25	32.38866
15	0.005263	20	40.48583
20	0.003	15	53.98111
35	0.001571	11	73.6106
50	0.00092	8	101.2146

Now we have to extract the data for different sedimentation rate as well as C_L so that we can draw the plot of LCL/AR so to draw this we have consider different time over here, let us say at 50 velocity is 0.00092 and here you can see this velocity we can have we have represented x which is equal to dz/dt basically it should be dh/dt, so that is the correction over here so at t = 50 velocity is 0.00092 Hi is 8 and C_L is this. This will value we have already seen, similarly at t =35 the value we have obtained.

And similarly t=20,15,10,7 and 5 so we can find the values of the values are different point so once w have this value x as well as C_L value.

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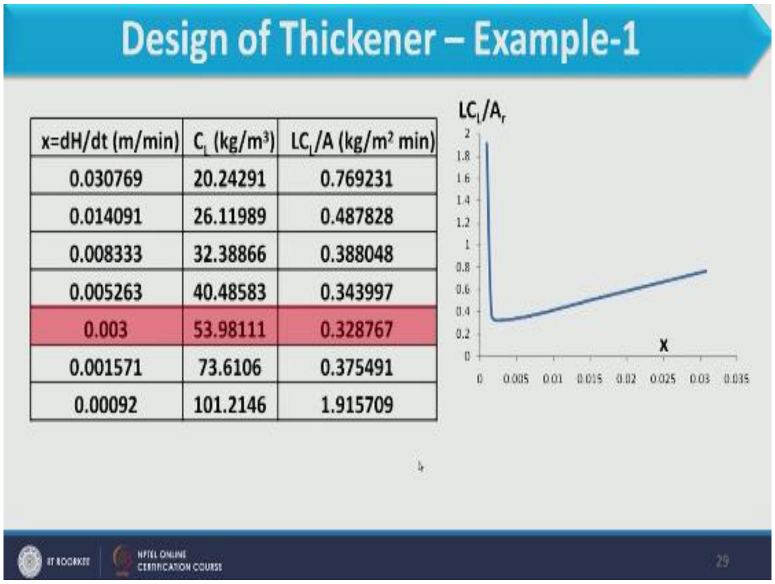

We can calculate LC_L/A so here in this slide we have the value of x as well as C_L and we can calculate LC_L/A LC_L/A_r so here e have the graph and if you remember the value of LC_L/A_r sould be equal to $x/1/C_L-1/C_D$ C_D is fixed and C_L and x are varying so based on that e can calculate LC_L/A_r so drawing this we can find the minimum possible value and that minimum possible value we can find as at x=0.003 which is 0.328767.

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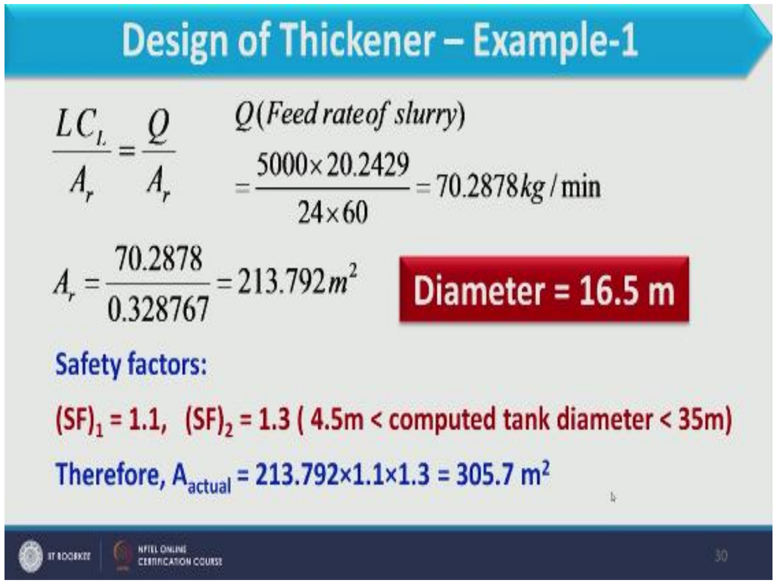

So once we have this minimum value we can calculate area corresponding to this but before tht we have to find the Q value and Q is the feed rate to the slurry, the slurry was feed as 5000 m^3/day so that is 5000x20.2429 that is C_F value so divide by 24x60 so total feed rate we have found as 70.2878kg/min so cross sectional area we can calculate as 213 diameter of this is 16.5m. Now adding the safety factor $(SF)_1$ 1.1 and $(SF)_2$ 1.3 w have taken because diameter is lying between 4.5 to 35 m therefore actual area should be 303.7 and corresponding to this we can, we have to calculate actual diameter of the tank.

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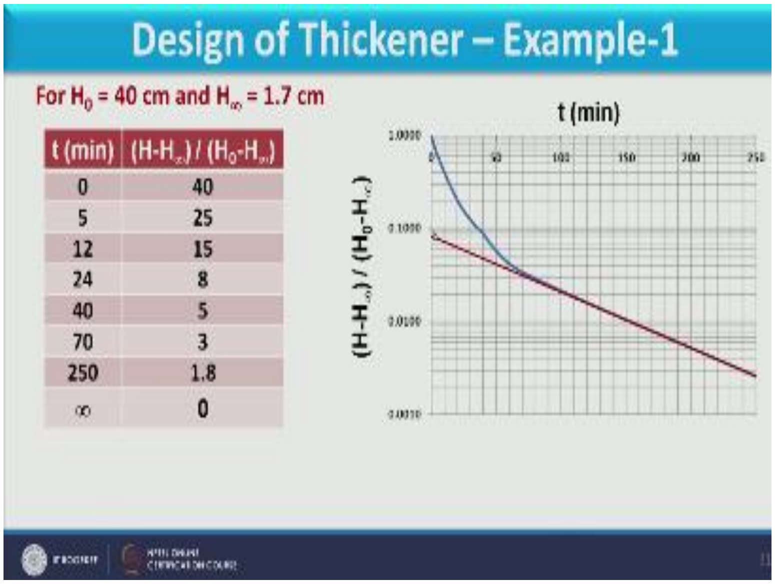

So to design of height of the tank we have to take the value of H_0 as well as H_∞ and that you can see from the batch sedimentation test for H_0 we have 40 cm value and H_∞ in this example is 1.7 cm so following this we can calculate value of $H-H_\infty/H_0-H_\infty$ at different time. So once we calculate this value we can draw the semi log graph where y axis is log and x axis is normal axis so once we have this graph we have to extend this line to calculate dc value that is critical sedimentation time so we have extended this up to here.

So that is the value of $\bar{y}$ so how we calculate the $y=1+\bar{y}/2$ and that will be 0.45 0.5415 so this value will lie somewhere here and corresponding value of t we can see from this that should be the T_C value and this T_C value is coming as 7 min. So critical sedimentation time is the 7 minute.

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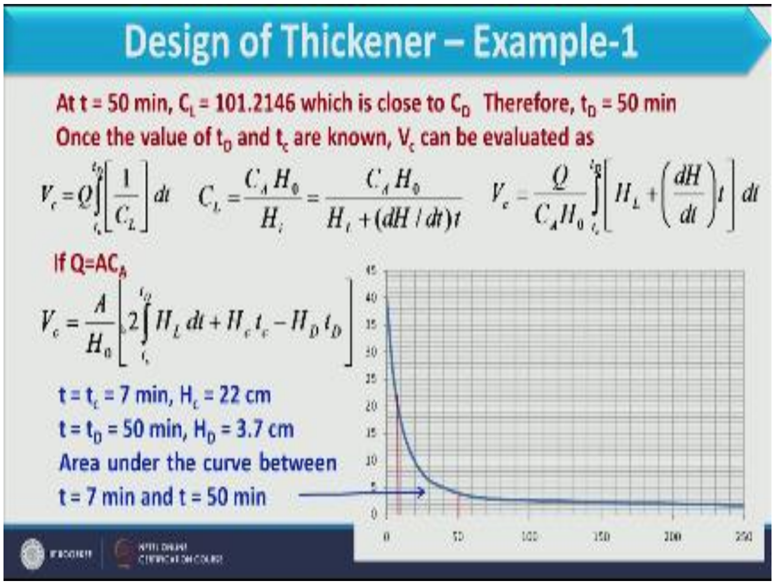

So at T = 50 minute C_L is 101.2146 that you can see from the table where times well as C_L values are available corresponding to T50 we have value 101.2146 that would close to the C_D value which is 106.

It defers but it is close to that therefore we can consider T_D as 50min once the value of T_D and T_C are known V_C can be evaluated as this the expression further C_L we can write as C_l H_0 / H_I after putting this values H_I value we can put over here which is nothing but the H_l + D_h/ D_t x T so V_C we can find buy this expression after replacing q with a C_A we have this A/H_0 / 2 H_L D_T H_l we have available over here in to D_T + H_C T_C – H_D T_D.

So here you see this expression we can write in this way so this is the final expression for volume of the compression zone. Now this D_H / D_T that we have replace with H_C T_C – H_D T_D because whole we have to integrate with the T_C to T_D, so this final expression we can find to calculate this we have to see the value of this and for this we have to draw h and t graph which is found through bad sedimentation test.

So here we have two value T_D and T_C if time $T = T_C$ that is the critical sedimentation time equal to 7 min we have calculated in the previous slide H_C should be equal to 22 cm and similarly $T = T_D$ =- 50 min T_D should be 3.7 cm, so area under this curve we have to calculate and this area would be equal to value of this.

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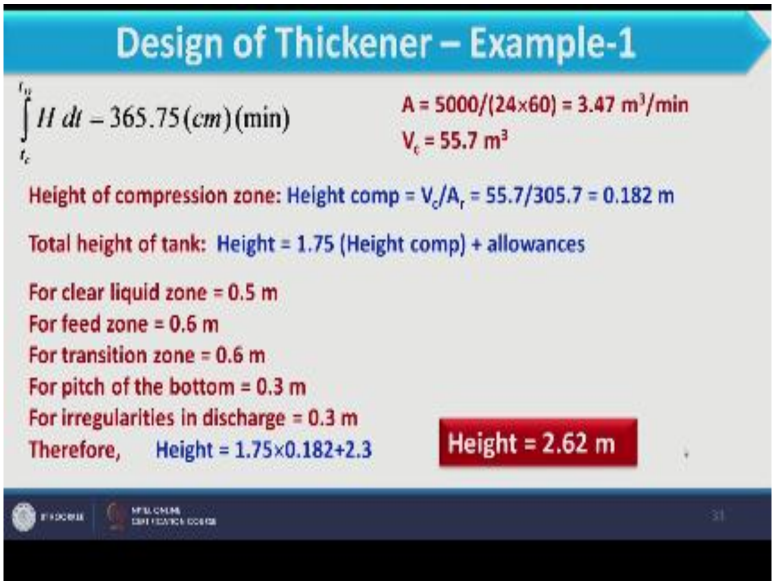

So value of this area is 365.75 cm min and A we can calculate ad that is the volumetric flow of feed that we can calculate 5000/ 24 x 60, so this 3.47m3 per min from the previous expression we can calculate value of V_c so height of the compression zone that is VC / AI that we have calculate as 0.182m. The height of the tank now is 1.75 height of compression zone + allowances. So here we have different factors for different zone.

So considering all these factors we can calculate total height of the column as 2.62m, so you can see here in this way we can solve the problem and we can design sediment to calculate the diameter and the height of the tank.

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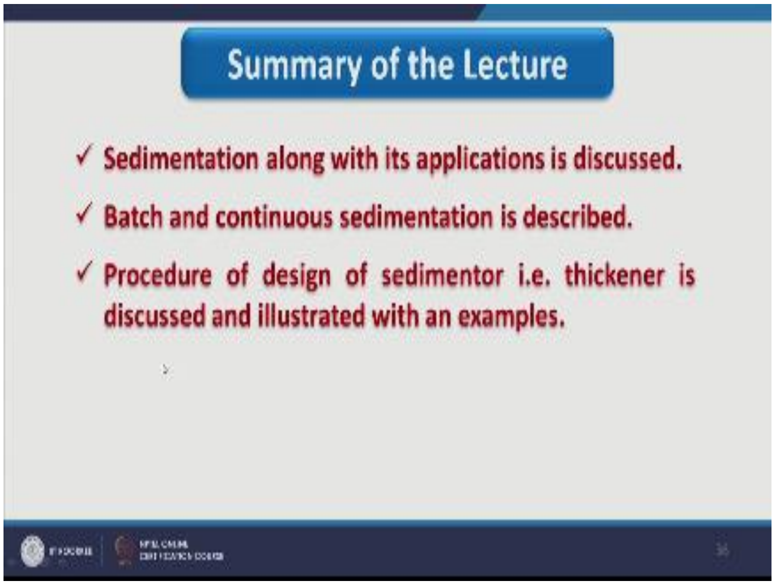

So here we have the summary of the lecture and this summary includes the summary of lecture 2 and 3 of week 1 which includes the topic sedimentation as well as design of thickener. So the summary of lecture 2 and 3 is sedimentation along with it is application is discussed. Batch and continuous sedimentation is described. Procedure of design of sedimentation that is thickener is discussed and illustrated with an example. So this is the summary and here we reference the books.

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Which I have referred for this lecture 2 and 3 and that is all for now. Thank you.

For Further Details Contact

Coordinator, Educational Technology Cell
Indian Institute of Technology Roorkee
Roorkee-247 667
E Mail: etcell.iitrke@gmail.com, etcell@iitr.ernet.in
Website: www.iitr.ac.in/centers/ETC, www.nptel.ac.in

Production Team
Sarath. K. V
Jithin. K
Pankaj Saini
Arun. S
Mohan Raj. S

Camera, Graphics, Online Editing & Post Production

Binoy. V. P

NPTEL Coordinator

Prof. B. K. Gandhi

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