INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Unit Operations of Particulate Matter

Lec – 08
Filtration and Batch Filtration (Part -03)

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Welcome to the 3rd lecture of week 2 and which is on filtration we are discussing filtration and we have already discussed this in lecture 1 and lecture 2 and here we will discuss filtration cycle and further we will solve a few examples based on filtration process, so let us start this filtration cycle now if you see the filtration cycle.

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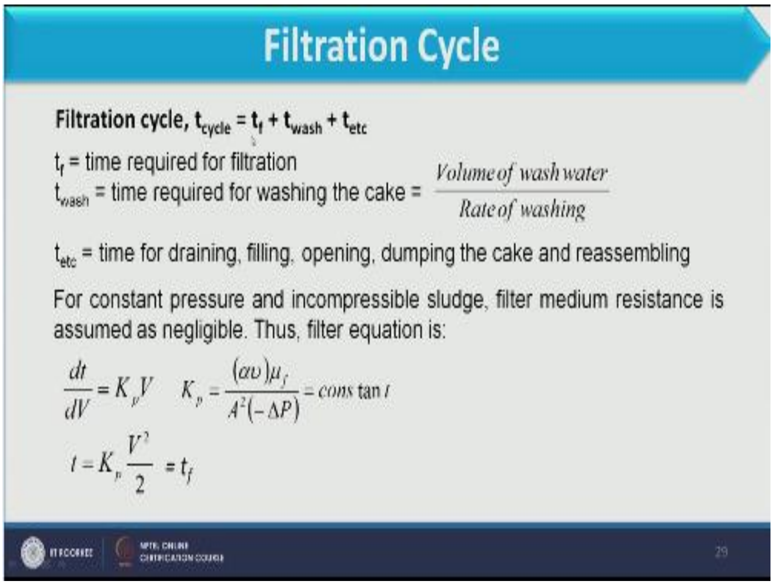

How the filtration cycle is defined is the time required for filtration time required for washing and time required for cleaning dumping and reassembling of the system so that complete time is basically called as the filtration cycle, so filtration cycle that is t cycle is defined as t_f + t $_{wash}$ + $t_{etc.}$ so t cycle is defined as t_f + t $_{wash}$ + t $_{etc.}$ t_f is the time required for filtration t wash is the time required for washing the cake that can be defined as volume of wash water / rate of washing and t $_{etc}$ is time for draining filling opening dumping the cake and reassembling here we are considering the case the constant pressure with incompressible slug and we are assuming filter media resistance to be negligible.

So considering all these factors we have the equation dt / dV – K_PV that is constant pressure and incompressible slug KP we have defined like this as we have seen in the last lecture so once we integrate it we can get the expression t – KP V^2/ 2 = tf because this t if is we see that will be the time associated with the filtration, so this t value we can equate to tf that is time required for flirtation.

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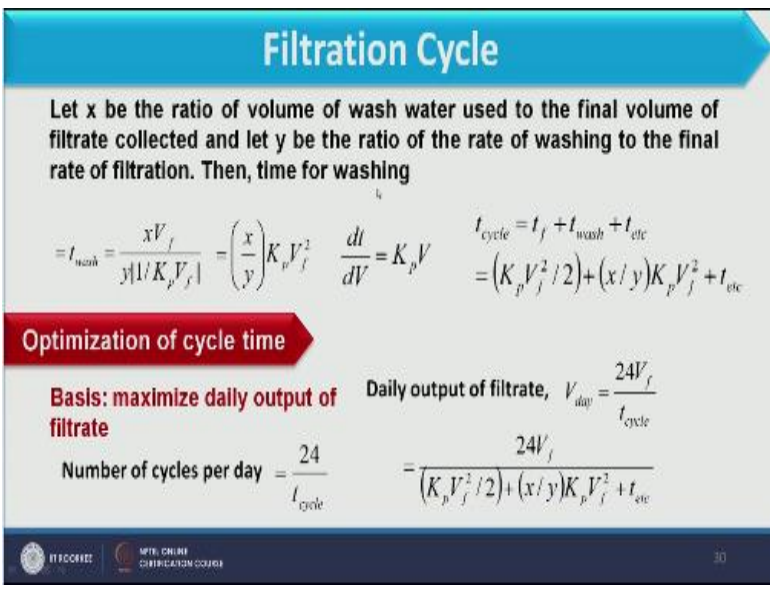

Now here we can define x which is nothing but the ratio of volume of wash water used to the final volume of literate collected it means x is the factor which is which gives the ratio of ratio between volume of water required in washing divided total volume collected during filtration process and why is the ratio of rate of washing to the final rate of filtration, so this x and y are basically relating the parameter associated with washing and parameter associated with filtration, so time required for washing is t wash = x V_f / y 1/ K_P V_f now x V_f, V_f is the final volume of filtrate that is collected and into x so that should be the volume of wash water and similarly y x 1/ K_P V_f now if you see the filtration equation when we consider d_V / d_t that should be the rate of filtration so it is value should be 1/KPV so that we have put over her and y is the ratio so this complete factor will give the rate of filtration.

So x/ y $K_P V_f^{\ 2}$ now t cycle is t cycle consists of t_f t_{wash} and t_{etc} putting the value of t_f and putting the expression if tf and t wash over here we can get this expression as t cycle now we have to optimize the cycle time and the bases of this we have considered the totals volume collected in 1 day that is the bases, so that volume which you have to collected that should we have to maximize to optimize the cycle time so number of cycles per day so 24 / t c_{ycl}e is the time associated with one cycle so 24 as we have to perform for single days so 24/$t_{cycle.}$

So daily collection of the filtrate V_f is the volume of filtrate collected in a single cycle so 24c / t_{cycl}e that it should be the total number of cycles into V_f so that we have defined as V_d now putting here the expression of t cycle this is the expression of Vd_{ay} that is volume collected in a day, now if we consider this particular expression V_{day} is a function of V_f

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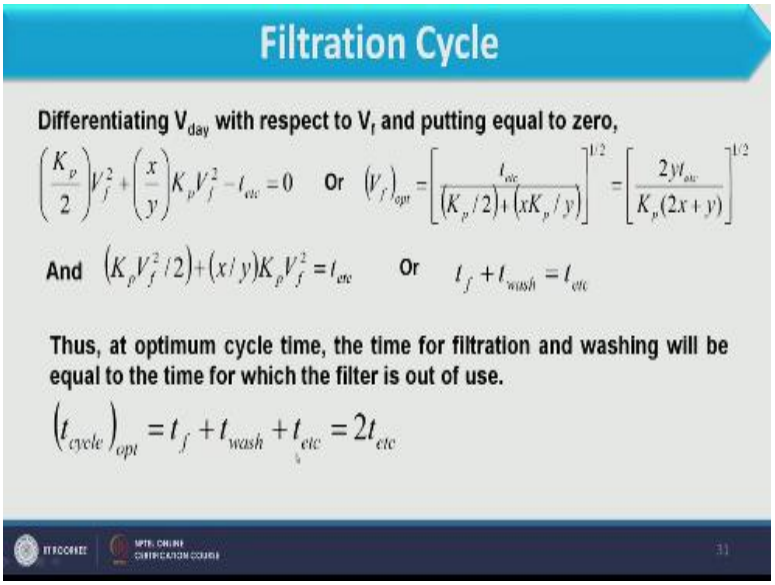

So differentiating V_{day} with respective V_f and putting = 0 we can get this equation and when we solve this we can have expression of V_f which should be the optimum value and it is expression is like this further after resolving this we can get this is the expression for V_f optimum now if we concentrate on this particular equation that should be K_P / 2 V_f^2 + x/ y $K_P V_f^2$ – t = 0 so we can take etc at this side and if you see this expression this we have derived for t_f and this we have derived for t wash.

So tf + t w_{ash} = t $_{etc}$. So when we consider constant pressure with incompressible slug considering 0 media resistances the optimum cycle for this optimum cycle time for this is the time required for filtration as well as washing should be = to the time required for dumping cleaning reassembling etc…

So here we have total optimum cycle time which is tf + t wash + tetc this should be = t etc so here we have optimum cycle time is 2 x t etc. So in this way we can defined the filtration cycle and we cam optimized the cycle time of filtration so that is all about the theory part now form here on wont we will discusses a few example which are based on batch filtration process so that you can understand what ever equations we have derived how we can utilize this to calculate the different parameter associated with the filtration process.

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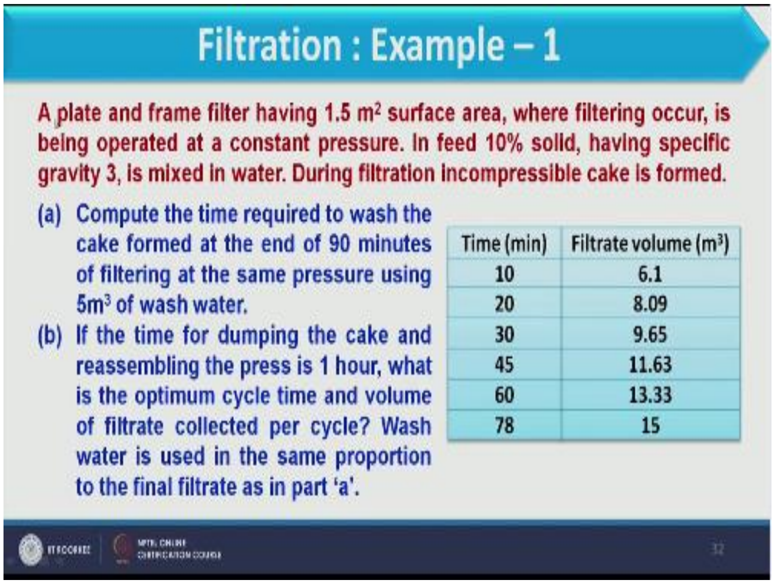

So here we have example 1. In this example a plate and frame filter now what is this plate and frame filter that we will discuss in subsequent lecture so a plate and frame filter having 1.5 m^2 surface area where filtering is carried out at constant pressure so you can say this is the constant pressure phenomena in the feed 10 solid having a specific gravity 3 is mixed in the water during flirtation in compressible cake is formed.

So this is the case of constant pressure and in compressible cake now what we have to do over here is in part a compute the time required to wash the cake form at the end of 90 minutes of flirting at the same pressure using 5m^3 of wash water so here we have to calculate the washing time and second part if the time for during the cake and reassembling the press is 1 hour what is the optimum cycle time And volume of filtrate collected per day wash water is used in the same proposition to the final filtrate as in part A.

So here first of all we have to calculate the time required for washing and then we have to optimize the filtrations cycle. So as for us operating data is concern this is the data we have optioned by batch filtration where according to the tome filtrate volume vary so this is the data for batch filtration.

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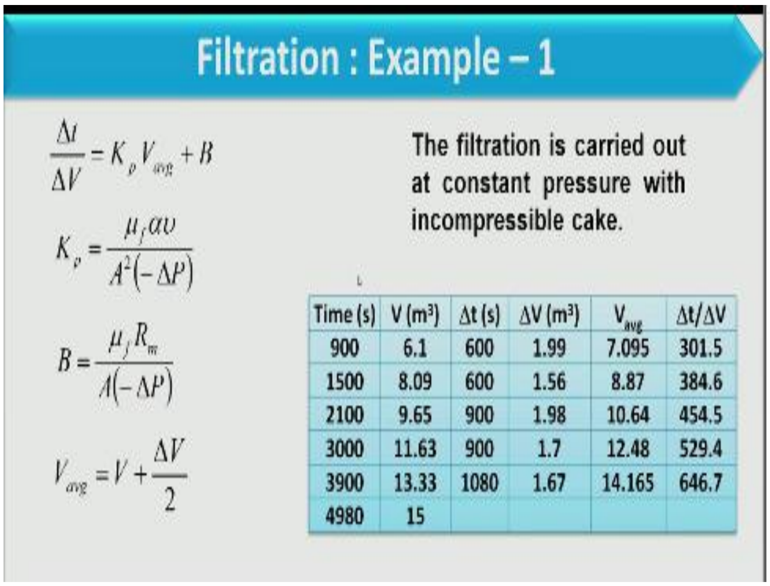

Time (s)	V (m^3)	Δt (s)	ΔV (m^3)	V_{avg}	Δt/ΔV
900	6.1	600	1.99	7.095	301.5
1500	8.09	600	1.56	8.87	384.6
2100	9.65	900	1.98	10.64	454.5
3000	11.63	900	1.7	12.48	529.4
3900	13.33	1080	1.67	14.165	646.7
4980	15				

So let so start the calculation of this the filtration is carried out constant pressure with incompressible cake so final equation is for this case as we have seen in the last lecture is Δt/Δv = K_p V_{avg} + B so here we have to plot the graph between Δt and between Δt/Δv and V_{avg} so first of all we will calculate these value, if you see the operating Δ for this we are given time and volume time is we write in a seconds and volume is in m^3.

So we can calculate Δt over here that is this time – this time and similarly this minus this that is squared easy calculation and here we have Δv difference in the volume so this minus this 1.99 further this minus this 1.56 in the similar line we can calculate other values of Δv. Now once we have the value of v and Δv we can calculate V_{avg} how that V_{avg} expression is if you see that is V + Δv/ 2.

So here 1 point so here 6.1 + 1.99/2 so that should be 7.095 and for other cases we can also calculate V_{avg} and here we have Δt as well as Δv division of this two will give these value now we can draw the graph between Δt/Δv and $V_{avg.}$

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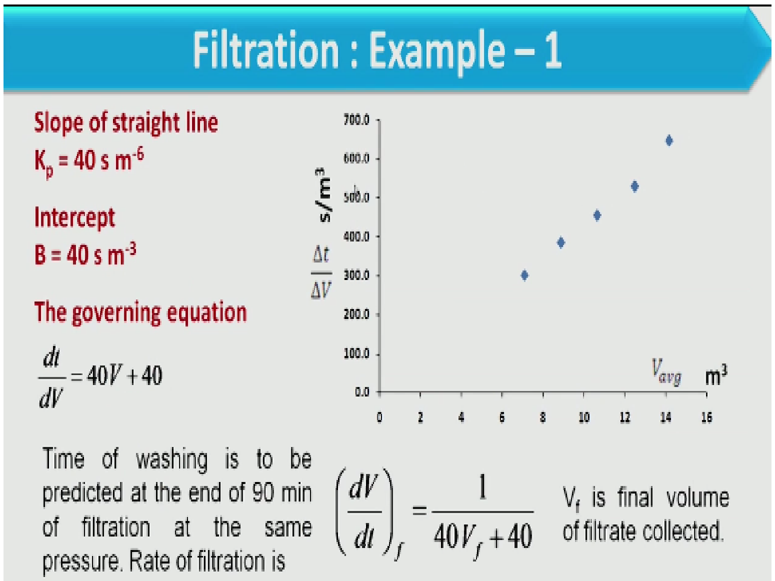

So once we draw the graph between Δt/Δv and V_{avg} here the few points are available and once we join these point we can get the straight line and slope of this straight line will give the value of K_p and that comes as 40 sec/per/meter^6 and when we see the intercept of this line that its value is 40 s/m^3 so governing equation becomes dt/dv = 40 v + 40 because all value of K_p as well as value of B both are 40 so we can get the filtration equation dt/dv = 40 v + 40.

Now if we reverse this if we reverse dv/dt that should becomes the rate of filtration so time of washing is to be predicted at the end of 90 minute of filtration at the same pressure, so here what we have to do is whatever rate of filtration at the end of 90 minute the same rate we can consider as the rate of washing because operation is carried out at same pressure. So here we have dv/dt F because we have used the final rate so that should be equal to 1/40 V_f + 40. V_f is the volume V_f is the final volume of filtrate collected at the end of 90 minutes.

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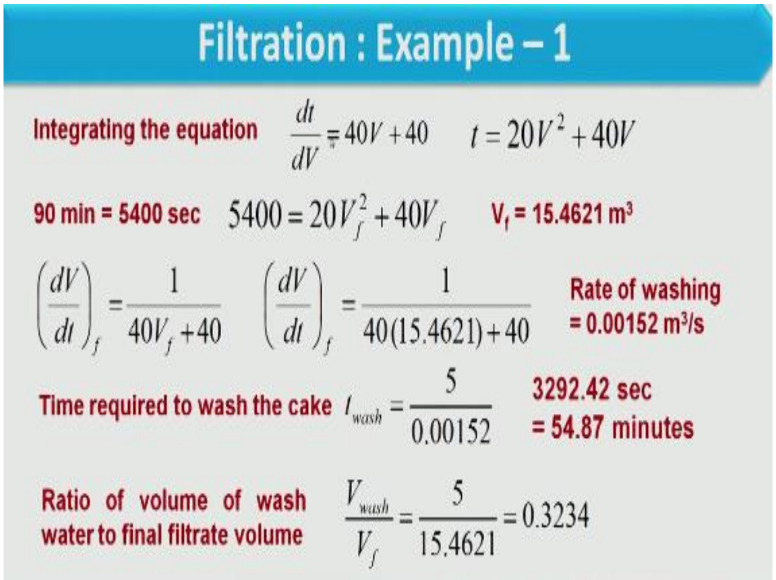

Now here integrating the equation which the equation we have obtained is this and when we integrate this for time the time comes as 20 v^2 + 40 v so total filtration is carried out for 90 minutes so that is 5400 seconds, so this 5400 second can be replaced over here and whatever volume is collected at 5400 second that should be the final volume of filtrate, so that we can obtain while putting 5400 as the value of T.

And we solving this equation we can find V_f as 15.4621 m^3 and final rate of filtration as we have seen in the last slide is dv/dt = 1/40 V_f + 40, now this V_f is the final volume of filtrate when we put its value which is 15.4621 over here, we can get final rate of filtration which should be equal to 0.00152 m^3 / s and here you can understand that as per the problem the rate of washing will depend on final rate of filtrations.

So rate of washing in this case should also be equal to 0.00152 m^3 /sec so we already know the rate of washing we know the volume of wash water used and that should be 5m^3 therefore time required to wash the cake should be volume of wash water / rate of filtration. So that comes as 3292.42 second that is 54.87 minutes, so here we have solved the first part of this, now the ratio of volume of wash water to final filtrate volume.

That is V wash/ V_f if you remember this factor we have defined as x so that factor comes as 0.3234.

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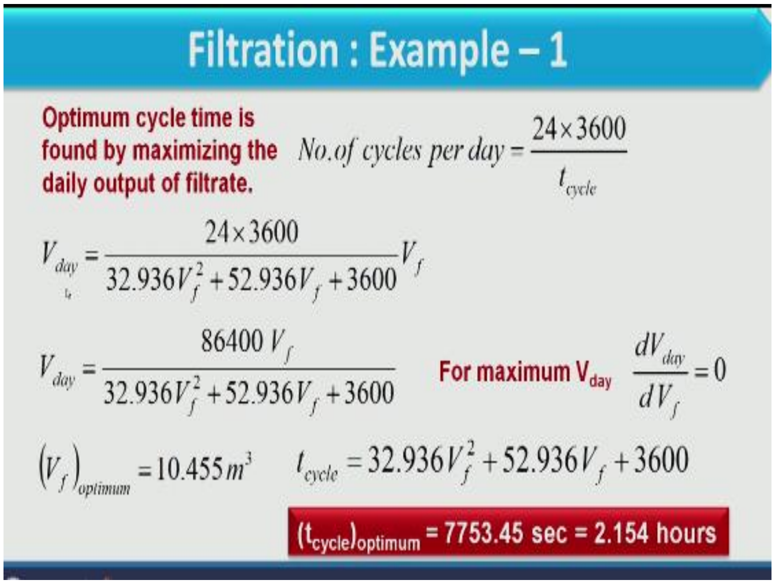

Now in part B we have to find the optimum cycle time and cycle time if you remember we have defined as t_f + t_{wash} + $t_{etc,}$ t_{etc} is given as 1 hour that is 3600 seconds, t_f is time of filtration that is 20 V_f^2 + 40$V_{f,}$ t_{wash} is volume of wash water/ rate of washing. So t_{wash} we can defined as this is the volume of wash water and this is the rate of washing as it is equal to final rate of filtration, after solving this we can get 12.936 V_f^2 + 12.936 V_f that is the expression of $t_{wash.}$

So I know the expression of t_f and t_{wash} while putting all these expression in T cycle here we can get the final expression of t_{cycle} in terms of V_f, now optimum cycle time how we can calculate this by maximize the daily output of the filtration process so in that case first of all we have to calculate number of cycles per day, so that should be 24 x 3600/ $t_{cycle,}$ t_{cycle} is a time required for one cycle and V_{day} = total volume collected in a day.

So V_f is the total volume collected in single cycle so that we should multiplied with total number of cycle. So 24 x 300 x V_f / t_{cycle} and further while putting all values of all known values we can get $V_{day} = 86400V_f$ / this expression that is the expression of t_{cycle} , now to maximize this V_{day} we will differentiate with respect to V_f and equate it to 0, so V_f optimum is 10.455 m^3 and t_{cycle} optimum cycle time is this much, so while putting the value of V_f over here we can get 7753.46 second that is 2.154 hours, so that is total cycle time which is already optimized, so that is optimum cycle time. So in this way we can calculate we can optimize the cycle time we can calculate total time required for washing.

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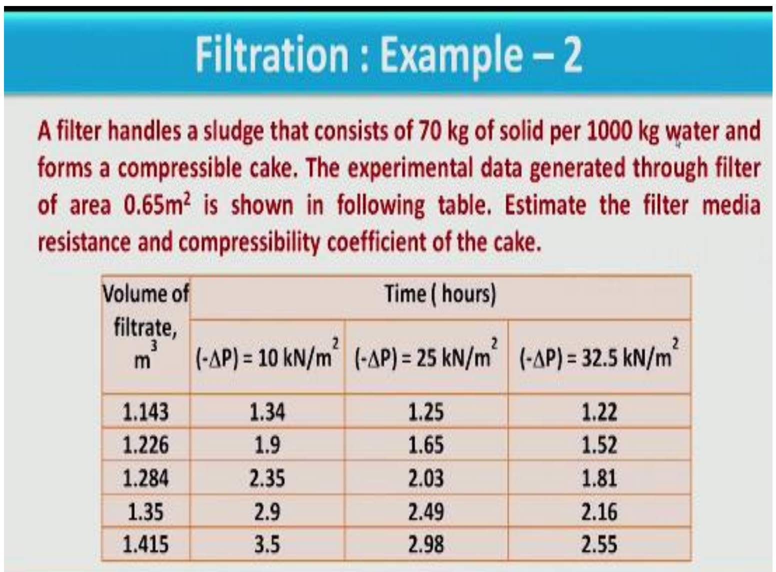

Volume of filtrate, m^3	Time (hours)		
	$(-\Delta P) = 10\ kN/m^2$	$(-\Delta P) = 25\ kN/m^2$	$(-\Delta P) = 32.5\ kN/m^2$
1.143	1.34	1.25	1.22
1.226	1.9	1.65	1.52
1.284	2.35	2.03	1.81
1.35	2.9	2.49	2.16
1.415	3.5	2.98	2.55

Now here we have second example, in this example a filter handles a sludge that consists of 70 kg of solid/ 1000 kg water and forms a compressible cake, so here you see the cake is compressible the experimental data generated through filter of area 0.65 m^2 is shown in following table, estimate the filter media resistance and compressibility coefficient of the cake, so what we have to calculate over her is, R_n value as well as S value.

The experimental data of constant pressure filtration is already given, now if you see this table here we have 3 values of pressure but for one pressure whole filtration process will be carried out and then the pressure value is change and then whole filtration process will be carried out then the pressure value is changed and then hold filtration process will be carried out so here we have though here we have three different values of pressure but this is constant pressure phenomenon.

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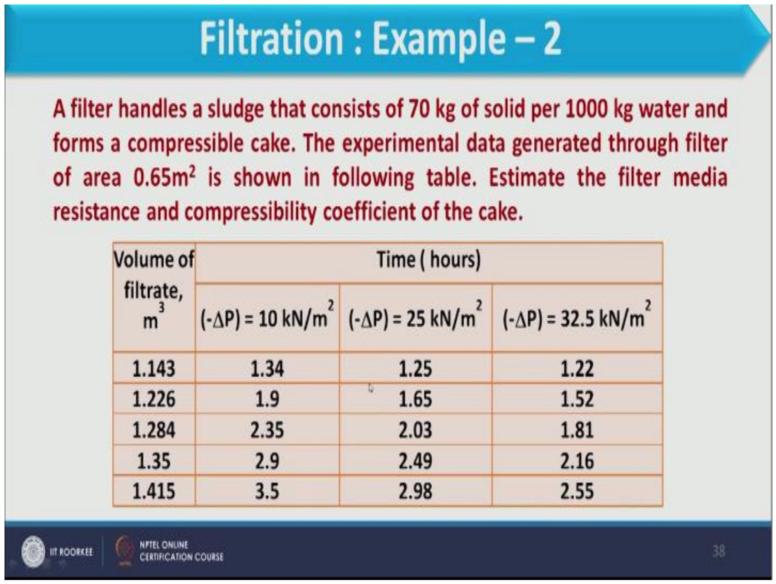

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1.35	2.9	2.49	2.16
1.415	3.5	2.98	2.55

Now if you see this the what type of case if this it is constant with compressible cake that is in the case and for compressibility and for α value we can use this peri correlation that is $\alpha_0\ (-\Delta p)^{s}$. So in this example R_m and s are to be calculated so this is the expression for constant pressure and compressible sludge $K'_p\ V_{avg}$ +B that is Δt/ΔV so here we have the equation for constant pressure and compressible sludge and that is $\Delta t/\Delta V= K'_p\ V_{avg}+B$.

So K 'p we have find out like this there we have we can found the value of s and value of R_m can be found by the value of B so here we have to find the Δt/ΔV and the average so Δt for all different pressures we can find at this discussing the last example ΔV we can calculate because volume corresponding time is known so ΔV we can calculate and for V average we can calculate.

As we have see in the last example and see only Δt/Δv it can be calculated for different pressures now what we have to do we have to draw the graph between Δt/ΔV at this average.

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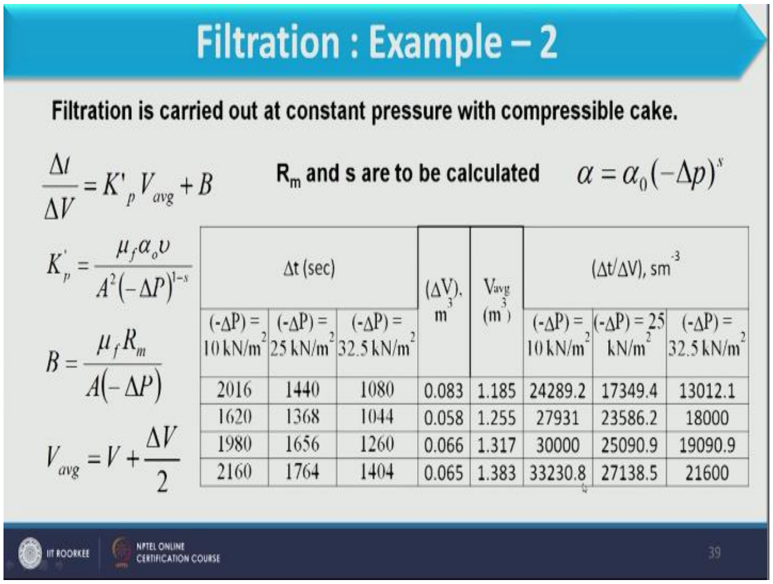

So you see here we have for three different pressures three lines are here so here we have three different pressures and therefore three different curve R_m at clearly in this graph it is drawn between Δt/ΔV and the average while drawing the line for each case we can find different slopes as well as different B values.

So for ΔP that is 10 if we consider this 10 so this is the graph it has K'p, K'p it has the slope like this and B we have like this so if you see all this graph we can conclude if we observe the slope it has a higher slope then this and then this. Similarly the values are appear in this table. We can also calculate from the intersect and those are available over here.

Once you know the value of B we can calculate R_m value because we know other factors other parameters so R_m can be calculated directly from the B value. So as we have three values three R_m value we will operate and every time these three R_m value will be the final value of R_m that is filter may be an resistance.

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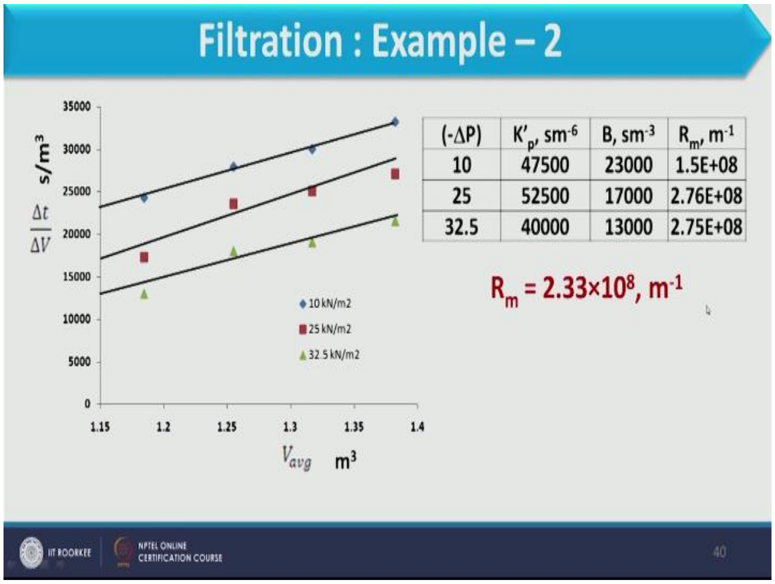

And that is obtained as $2.33*10^8$, m^{-1} and now further you will use the data of pressure drop which we have seen from the last curve pressure drop and K'p so here we have three pressure drop values and three K'p values. The K'p expression when we take log of the case this is the final expression and here K'p will be become on pressure drops.

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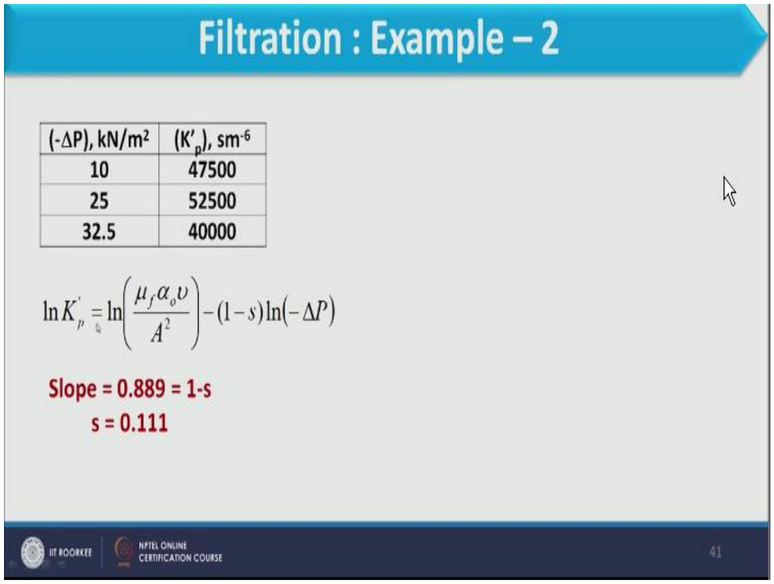

So K'p verses pressure drop we can draw here we have three points so three points re nearly over here now you see here if we consider this particular section as well as this section this is an X axis if we consider this Y axis and this X axis these are nothing but the logical axis. Now for this three points when we draw the line the line will be like this and slope of this line will be negative so that is -1-s.

So if we consider the value of this that should be equal to 1-s which is .8889 so from here we can calculate value of s which comes as .111 so in this we can calculate factors which are associated with the filter as well as compressible cake.

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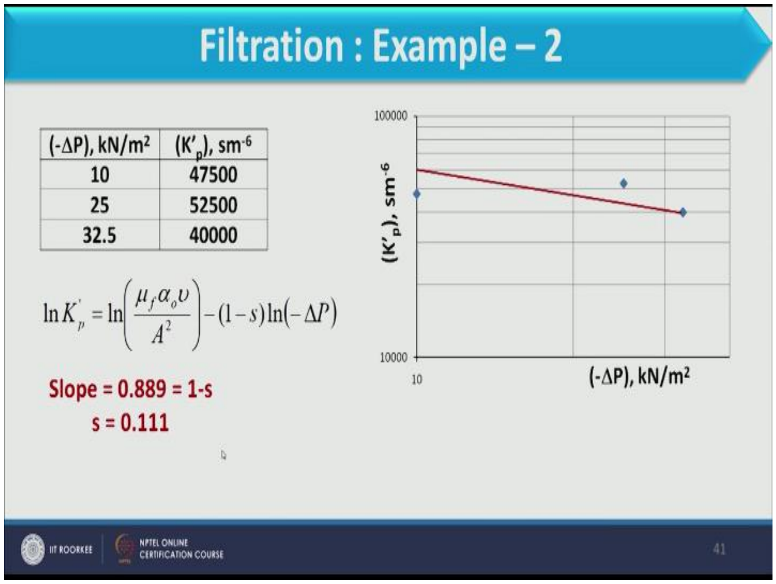

Now here I am considering third example were a sludge in a washing plate and frame filter press is of such nature that the filtration equation is $V^2=Kt$ where V is the volume of filtrate obtained in time t, when the pressure is constant. $40m^3$ of filtrate is produced in 10 hours. $4m^3$ of wash water is used for washing at the end of filtration.

So what we have to calculate the washing time if washing rate is $1/3^{rd}$ of filtration rate and secondly filtering surface is double, remaining other conditions constant, how long it take to produce $25m^3$ of filtrate.

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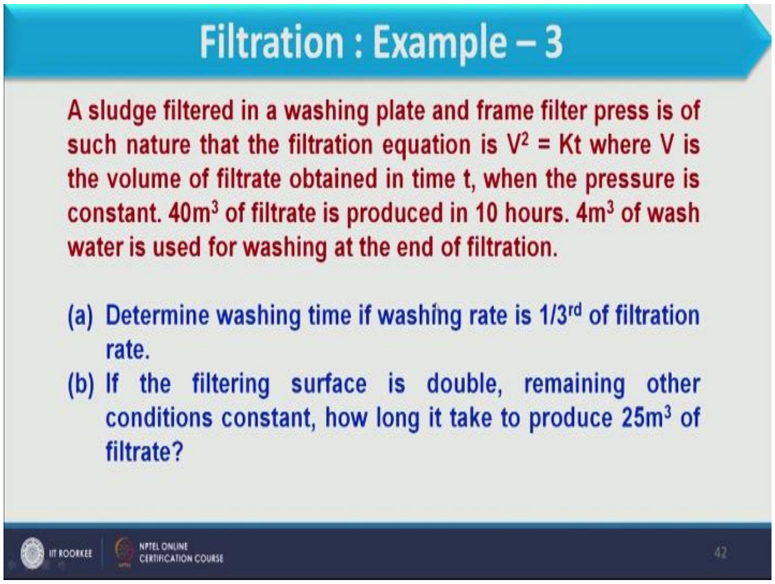

So let us start with part 1 filtration equation we have given like this V^2 = Kt dV/dt=K/2V which is nothing but the rate of filtration now in part a time t=10 hours volume is given as 40m3 so when you put this values over here we can find value of the constant V that should be V^2/t so the value comes as 160m^6/h and rate of filtration should be k/2V that we can found as 2m^3 /h.

So washing rate if you see washing rate is basically consider as 1/3rd of the rate of filtration so 2m^3/h is the rate of the equation so washing rate of filtration the rate of washing should be .667 1/3rd of that. Therefore washing time should be total volume of the wash water we are using divide by .6667, so 6 hours should be washing time.

Now part b as it is constant pressure phenomena it is denoted as expression should be dt/Dv= K_pV+B where kp is we find like this in the present problem dt/dv=2 V/K.now we come to this equation with the above equation we can correlate that k is proportional to the A^2 so when we double the revised coefficient should be 4 times then the previous one.

So revised coefficient value should be 4*160 160 is the previous coefficient values so final k' should be 40m 6 per hour time to produce 25m^3 of filtrate that should be V^2/K' is which you see the phenomena equation volume we can put as $25m^3$ solving this we can get .976 hour that is 58.6 minutes.

Now here we would like this to see should be the time required to generate for $40m^3$ of filtrate then filtered area when area of filter is doubled so in that case because k is proportional to area square so when we doubled the area 4 times for $40m^3$ for generation of $40m^3$ of filtration will required 2.5 hours instead of 10 hours.

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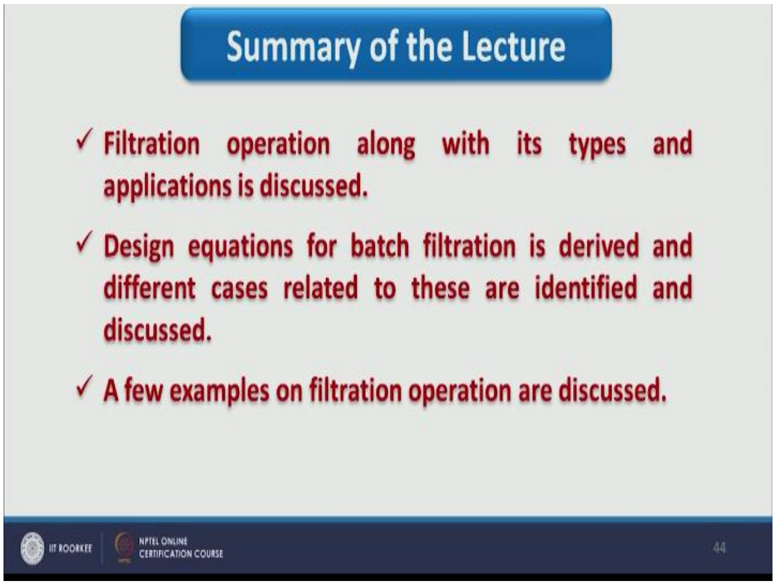

So you have seen the examples we make you to understand how the equations will be used to calculate the factors as well as you see the equation process so here we have the summary of the lecture and you should keep in mind that the summary is for lecture 1 2 and 3 so in this series the 3 lectures filtration operations along with its types and operation is discussed.

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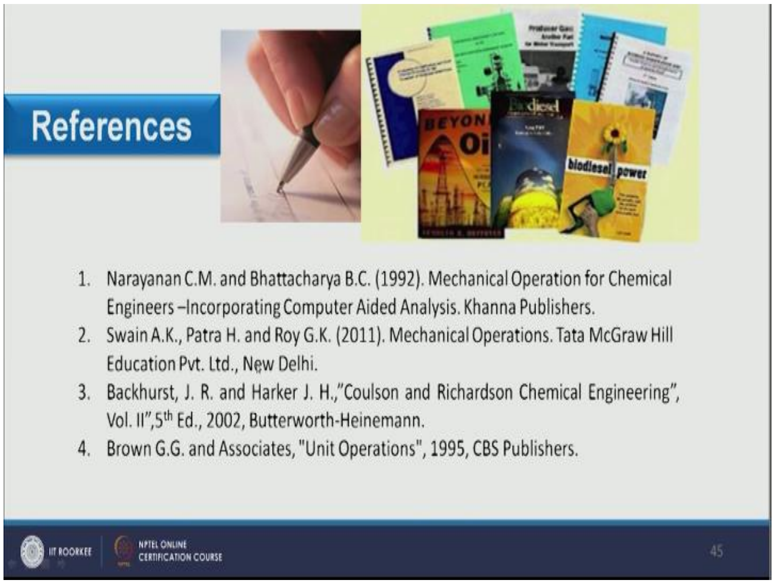

A design equation for batch filtration is derived and different cases related to these are identified and discussed. A few examples on filtration operation are discussed here you have the references through which is studied about filtration in detailed and that's all enough. Thank you.

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