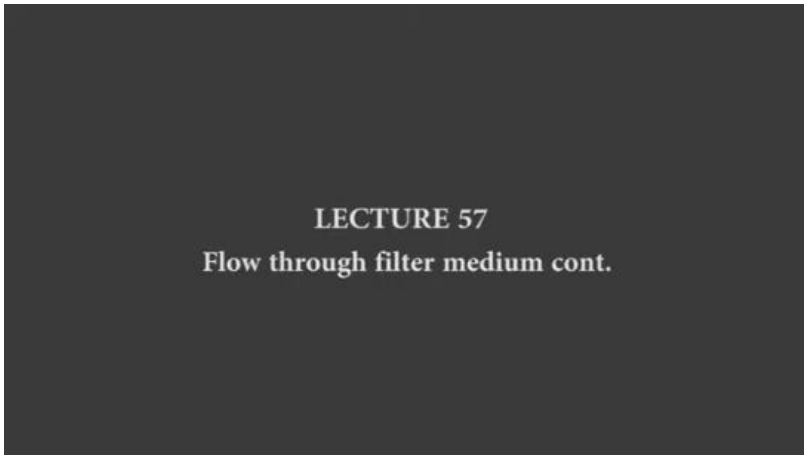
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

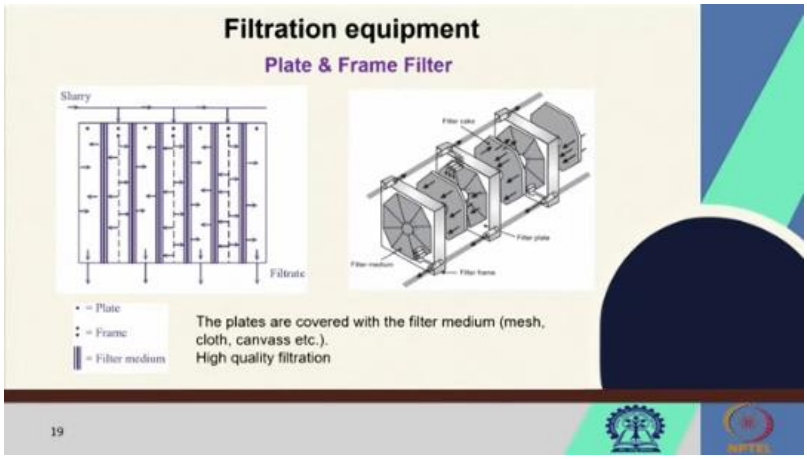
Lecture57

LECTURE 57 : Flow through filter medium cont.

Welcome back friends. So, 12th week of the lectures. So, we have been discussing about the flow through filter medium. And in the last class, what we have looked at, we have looked at the basics of the filtration mechanism, very fundamentals of it, different kind of applications where they are applied, including food and beverage industries, where the filtration is really is the



core step in the food and beverage industries. And also we have looked at different kind of filtration mechanisms and the separation mechanisms like you know cake filtration, clarifying filters and also cross flow filters. Now in this part what we will be looking at we will try to look at very briefly what the what kind of equipments are used. So there are many equipments used but we will try to look at very few ok. Now coming to the you know filtration equipment.



So, first we are coming to the filter press in generic name is the filter press. So, specific equipment name is the plate and frame filter. So, what filter press means? So, there is a press will be used the filter medium will be there and fluid or slurry will be flowing through it ok. This is basically

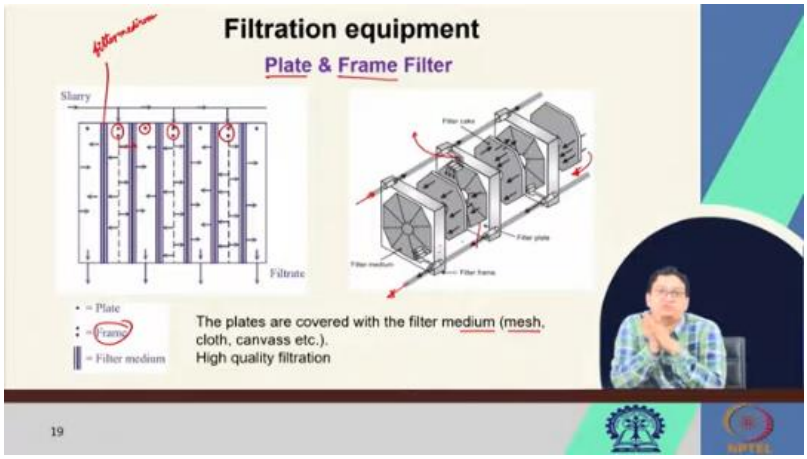
The pressure-driven process and batch process, ok. You look at this picture; let us look over here, ok. So, plate and frame. So, there are two parts: plate and frame. If you look at it.

So, there are, you know, plates there. So, let us say this is actually the filter plate, ok. On the filter plate, the filter medium is provided, or many times it is called, as I said, septum is provided; filter medium is provided, ok. Maybe it is cloth or any kind of membrane. So, this one is the filter frame, ok, and these are the frames with the filter plate; they are actually clubbed all together, they are actually squeezed together, ok. There are passages that allow the slurries to flow in and the permeate or filter to go.

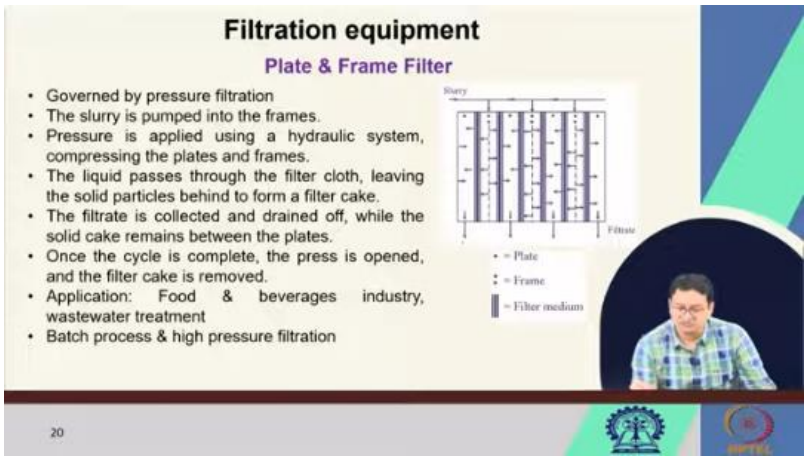
Now, you see over here, the slurry goes in here in this part. If you see, there is a provision there that slurry can pass through this filter membrane, that means through the plate. The moment this passes through this filter medium; the cake will be deposited eventually. Like the remaining part also, it can pass through and can be further filtered. Come like this, ok.

So, while it is passing through like this in this other, you know, delivery channel, you will get it filtered out, okay. Now, look at this picture, okay? Same thing. So, this one is the filter medium. This is the filter medium, okay. Here we have the frames, so this one—so double dots—these are actually frames, okay, and this is actually a plate. So on the plate, you have this filter medium over here. Now, this is the slurry. The flow is coming like this, okay? So here is the filter

frame, okay? When it is passing through this filter medium, the cake will be deposited onto the plate, okay. So the plates are usually covered with the filter medium, which could be mesh, canvas, or sometimes cloth, okay. The filtration quality is very high, and it is used in, you know, wastewater treatment, food, and beverage industry based on the requirement. So that's the idea. So that's why it is called plate and frame. So plates are used for holding the mesh or the filter medium, and they are actually clamped all together using a frame. So, that is called the plate and frame filter. This is a batch process.

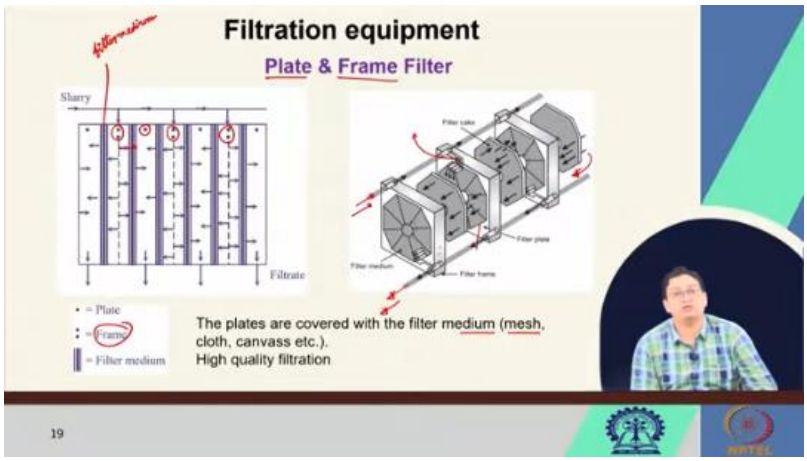


So here, the theories are actually provided. I have already explained about it. But let me go through it a little bit. So, as I mentioned, it is governed by, you know, pressure filtration. The slurry is pumped into the frames.



So, slurry is pumped into the frames. Pressure is applied using a hydraulic system, compressing the plates and frames. Now, when it is passing through the liquid and the filter cloth, what will it do? It will form a solid cake deposit. So, it will give us the filter cake.

Now, the filtrate is collected in another delivery channel and will be drained off, while the solid cake remains between the plates. Now, you see from the very start, when it is altogether clubbed, the slurry flows occur and it comes out. So, the whole thing. Starting from pumping the slurry, closing or shutting all the equipment, to the end of the filtration cycle, including washing. So, why is washing required? Because there is a formation of



cakes, and the filter cakes also have voids, meaning pore spaces. In these voids or pore spaces, there will be a high chance that some liquid material will be there, entrapped with some essential materials. Even in the filter cake, there will be some soluble solids that are very valuable, so during the washing process, they can be recovered. The whole thing is actually called one cycle. Now, you see that one cycle—the time of the cycle—is much longer than the formation of the cake because when the slurry starts flowing, starting from

the very beginning, immediately the cake does not form. So it takes some time. So the formation of cake and the time required is less than or a fraction of the total cycle. Once the cycle is complete, the press is opened and the filter cake is removed. As I said, the application is in the food and beverage industry, wastewater treatment, batch processes, and high-pressure filtration. Now, coming to one of the continuous types, this is called a continuous rotary drum vacuum filter.

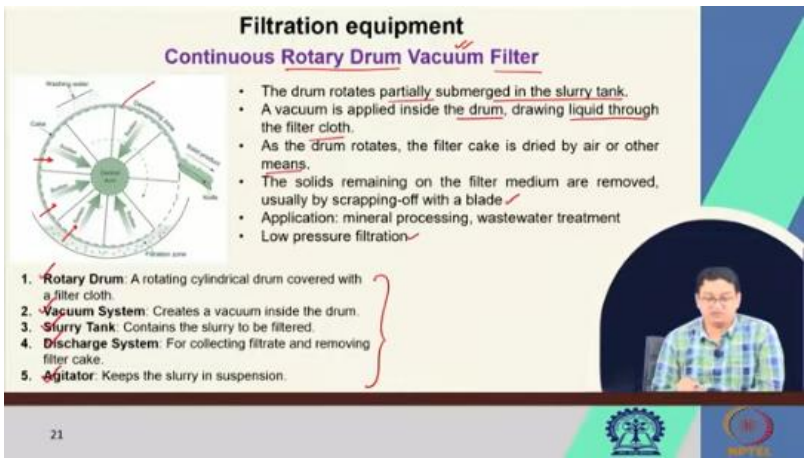
As the name indicates, it is a rotary drum-type equipment, and it applies vacuum for the filtration process, and it is a continuous process. So, let us look at this figure. So, in this figure, if you look at it, this is actually a rotary drum. So, this is the one, actually your rotary drum. Here we have

your sludge, or rather I would say, slurry. That has to be filtered. So it rotates. We have a central duct that can apply the vacuum. On the surface, we have slots, that means openings.

And this one is actually covered by the filter medium, maybe the filter cloth. Now, when it rotates, there will be suction applied using the central duct. So, the moment suction is applied, what will we have? So, the slurry will actually be sucked through the slots and pass through the filter medium. So, the solid particles will be deposited on the surface.

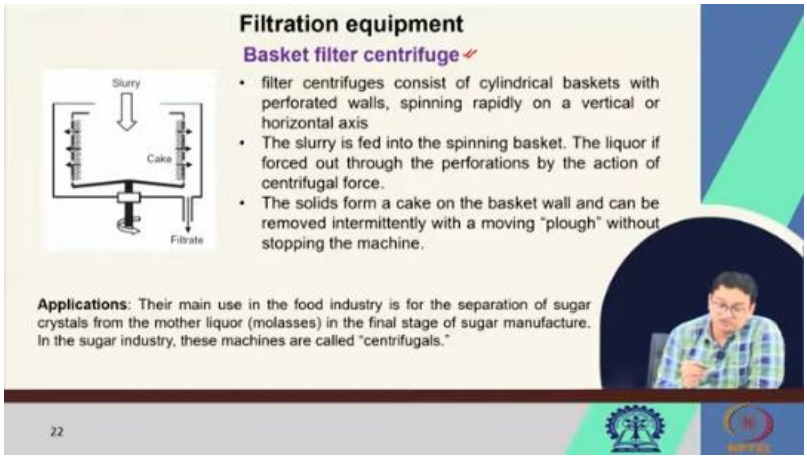
So, the liquid will go in. So, there will be a formation of the cake, and we can have the washing water. And a dewatering zone, and we can use a doctor's blade or knife to slowly scrape the cake from the surface of the rotary drum. The rotary drum rotates partially submerged in the slurry tank. So, this is your slurry tank over here.

Vacuum is applied inside the drum, drawing liquid through the filter cloth. As the drum rotates, the filter cake is dried by air or any other means, and the solids remaining on the filter medium are removed. Usually by scraping with the blade, and applications are in mineral processing, wastewater treatment, and low-pressure. Filtration. And this one actually shows the different components: rotary drum, vacuum system, slurry tank, and. Discharge system and agitator. So, this is the basic idea of the rotary drum vacuum filter.



So, this is continuous type the previous one is the batch type. So, there are many other types are also available we are we will not be going into the detail we will look into the one more type that is called actually centrifugal type in basket filter centrifuge the name

is called basket filter centrifuge. So, what happens if you look at the picture. So, this is actually you have a casing. Here we have the wall over here.

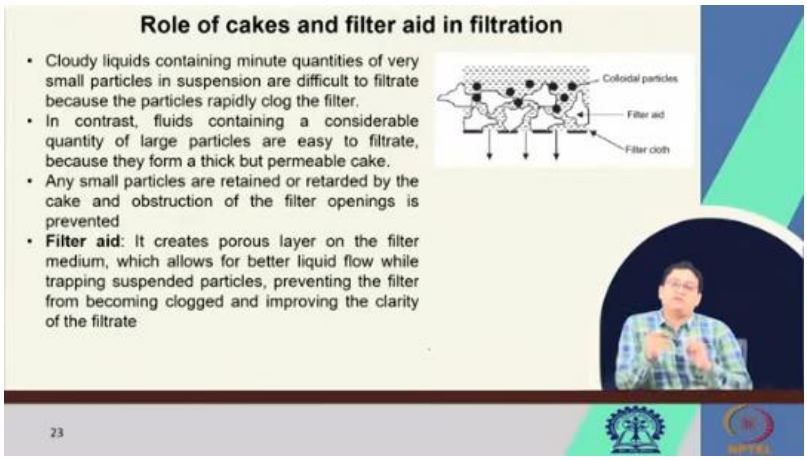


That is actually we are having some porous material. This basket, this basket can spin. It can rotate at very high speed. Now, the filter centrifuge, sorry, the slurry is fed into the spinning basket. The liquor is forced out through the perforations.

So, these are the perforations by the action of the centrifugal force. So, when it rotates at very high speed, there will be a centrifugal force generated. And the liquid will pass through these openings. We will have some filter, you know, medium over here. And eventually, as you put more slurry in, there will be a formation of the cake.

The solids from the cake on the basket wall can be removed intermittently. So, what are the main applications in the food industry for the separation of sugar crystals from the mother liquor molasses in the final stage of sugar manufacturing? In the sugar industry, these machines are called centrifugals. So, that is the basic idea of where it is actually being used—the filtration equipment. This one is the centrifugal type.

All right. Now, coming to the roles of cakes in the filtration process and what is the filter aid. Now, what happens is that many slurries or, you know, many materials that have solid particles with smaller and smaller particles make it very cloudy or hazy, and those smaller particles can easily clog the pores of the filter medium and can also be sticky in nature.

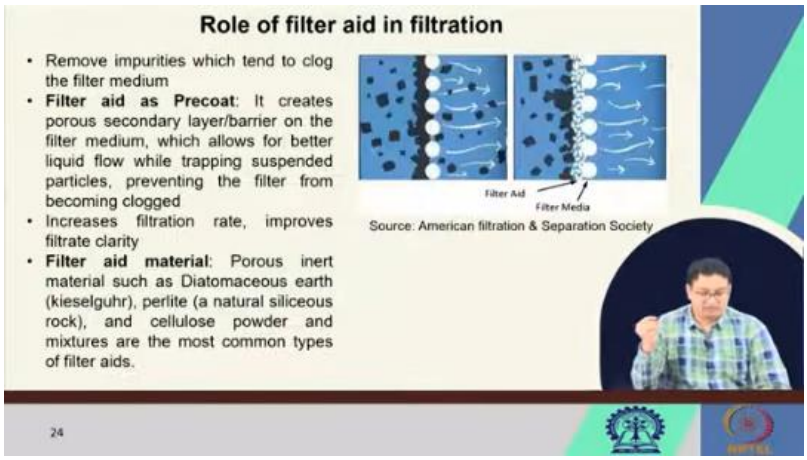


So, when that happens, it becomes very difficult to make the filtration process effective. Now, what happens? If it clogs the pores, the filtration process will slow down, and you will not have a very efficient filtration. So, what do we do? We add some filtrate.

So, you imagine that during filtration process the cake is also you know taking part in the whole filtration. So, here we talk about the cake filtration mostly we are focusing on the cake filtration part. If the smaller particles as I said is very you know sticky in nature it is very difficult to separate them out. So, in that case we add the filter aid. So, what the filter aid is it uses as pre-coat. So, the filter aid it creates a porous layer on the filter medium

which allows for the better liquid flow while trapping the suspended particles mainly smaller or sticky in nature filter from becoming clogged and improving the clarity of the filtrate. So, as I said the small particles are retained and retarded by the cake and obstruction can happen. So, here if you look at the pictures. So, filter.

So, this one is the let us say filter medium and filter aids are added. So what they do actually some particles they are being arrested using the filter rate and you can remove the also filter rate time by time so that we can add more filter rate so that we can have a more efficient separation or filtration process. So here it is showing that filter rate is used as a pre-coat. Pre-coat means the coating on the membrane ok.

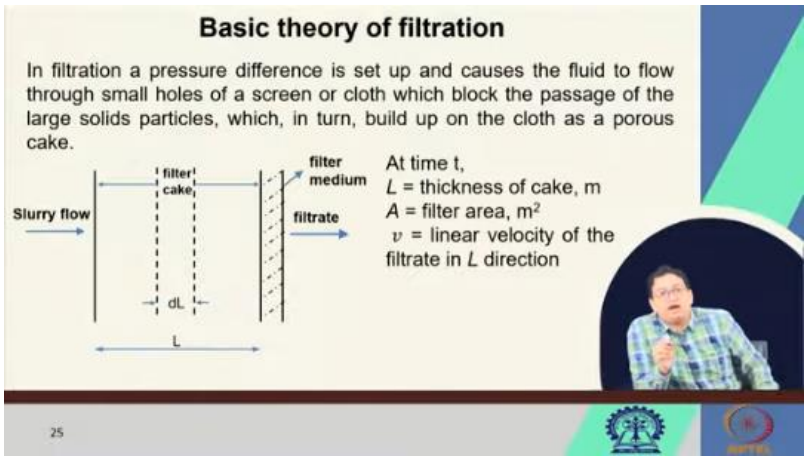


It creates a, as I you know mentioned earlier it creates a secondary barrier layer onto the filter medium which allows for the better liquid flow while trapping the suspended particles. So, it is many times also called pre-coat. Pre-coats are used for the better filtration techniques. If you look at this picture over here. So, the first one it does not have any kind of you know filter aid or pre-coat.

So the particles, it can easily clog the pores while it is passing through. Now the filter head, so this one is the filter head. When the filter head is being used, so they are actually being arrested over here and rest of the things it can go out. And what are the actually materials are used? Keisel gourd.

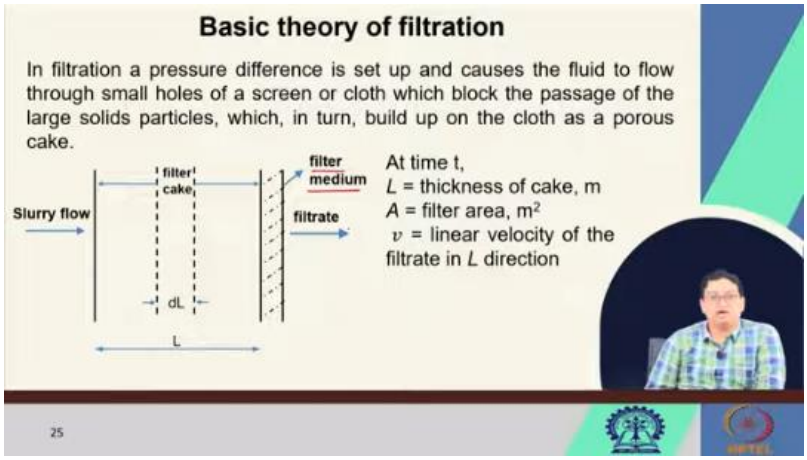
So it is called diatomaceous earth. Perlite also used is a natural siliceous rock and cellulose powder and the mixture of many common terms of filter rates can be used. So, over the period say let us say it is getting deposit it is strapping the material over here you know small let us say if you have a rotary type or continuous. We can have a small doctor's blade that can scrap out the top part of it. Then we can add more.

Because if you can scrape out the top part, the efficiency will be much higher because it will remove these materials. Then we can add more. So we can add more so that it can trap more particles. So this is the filter aid. Now we will come to the basic theory of filtration. So far, what we have learned about filtration



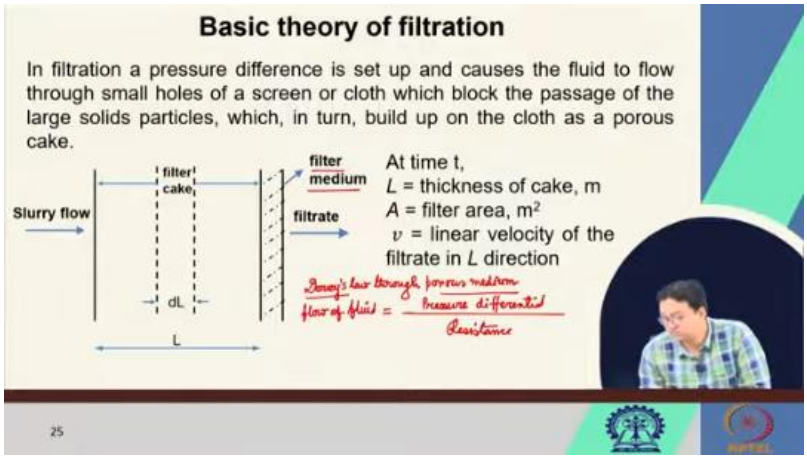
techniques—what are the different kinds of filtration equipment used—not all of them have been covered, but a few important ones have been covered with a brief overview of how they actually perform filtration. Then we looked at what the filter rate is and the use of the filter rate. Now, coming to another part: the basic theory of filtration. When we start with the filtration theory, we will mainly focus on the cake filtration type. That means we have a filter medium, the slurry is flowing, and over time there will be a deposition of solids, leading to filter cake formation. We will get

the filtrate out. Now, it is a pressure-driven process. The pressure difference is set up, and that will actually make the fluid flow occur through the small holes of the filter medium. Now, this filtration process is actually driven by Darcy's law. So, Darcy's law of, Darcy's law for, Darcy's law through porous medium—Darcy's law through porous medium.

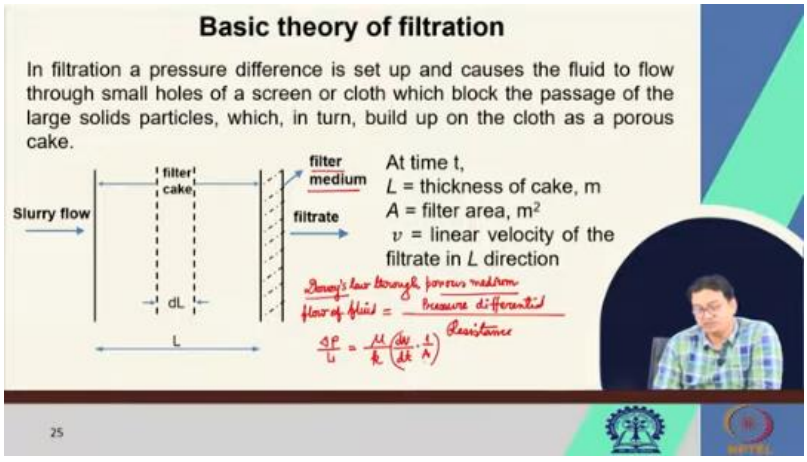


So, what it does? It says so see. So, what is the basic idea? So, flow of fluid or flow of fluid that depends on the you know pressure differential divided by the resistance.

So, that is the basic idea. That means flow of fluid means we are talking about the rate of filtration over here. So, the pressure differential is the driving force and here is the resistance. Now, what it says the Darcy's law of you know fluid flow through the porous medium it says actually if you write it delta P by L equals to mu by small k dV / dt divided by, now, the resistance part comes over here this one dV / dt see V is the volume of filtrate.



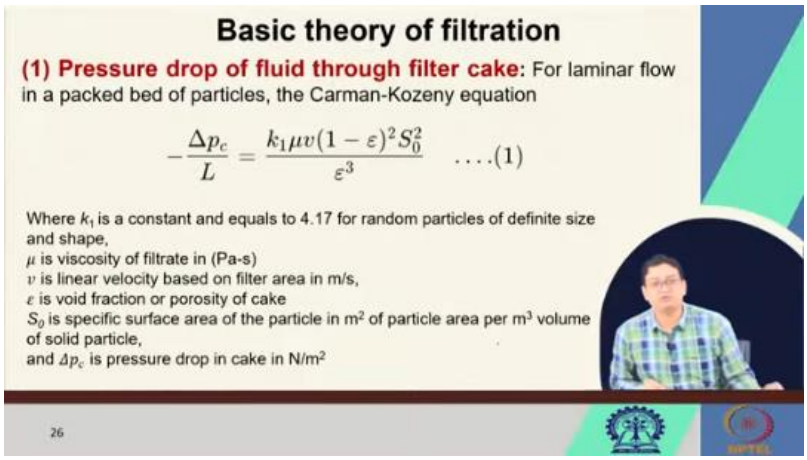
So, capital V is the volume of filtrate meter cube per unit time it has the unit divided by the cross sectional area or the area of the filter. That means, meter cube per second divided by meter square it gives us the filtration that means, meter per second. So, if you look at dv / dt by 1 by A equals to 1 by A equals to delta p let us write this way divided by mu by k. That means this top part is the pressure differential, pressure gradient, delta P by L., L is the thickness of the cake.



Mu by K acts as the resistance over here. So, the pressure differential is determined by resistance. So, it will actually follow Darcy's law through the porous medium. Now,

coming to the pressure drop of fluid through the filter cake. Now, this permeability part—if you look at it—perhaps you have learned about flow through a packed bed.

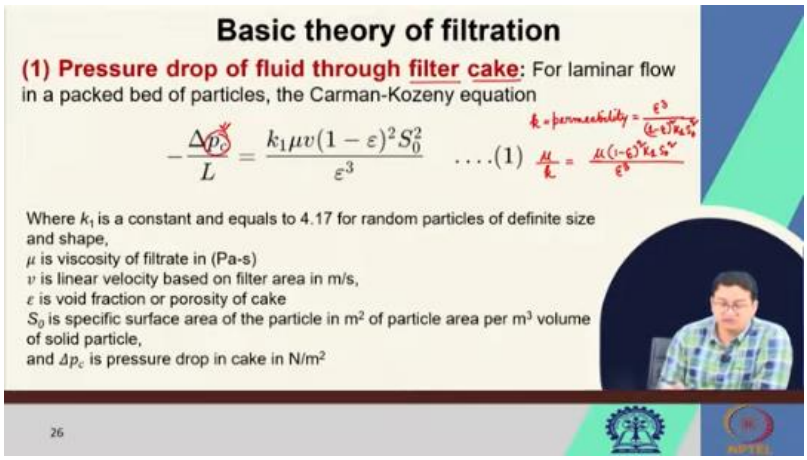
So, you can imagine this as a packed bed. Now, quickly, I will just explain over here. Now, this resistance occurs due to the presence of the filter medium's resistance and also the resistance provided by the filter cake. So, two resistances are actually in series. Now, this permeability—that is, small k—is written as epsilon cubed divided by 1 minus epsilon squared, multiplied by k



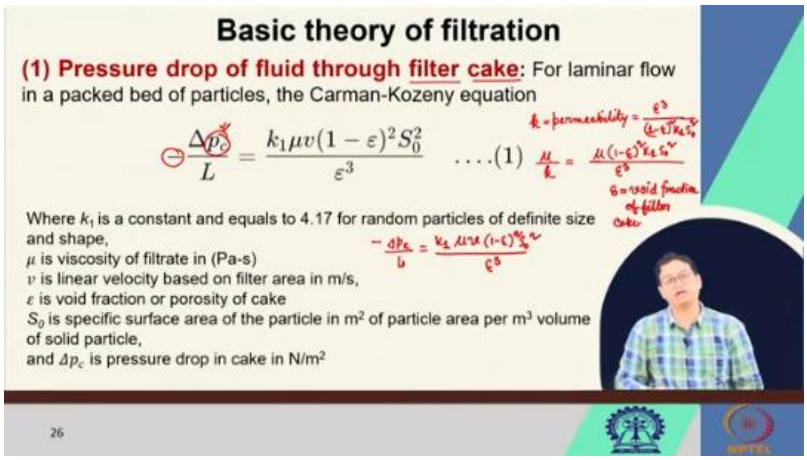
1 divided by S_{naught} squared. So, that means if you have mu by k over here. So, you will get mu multiplied by 1 minus. So, we are coming from over here: delta P by L divided by mu by K. K_1 S_{naught} squared. Now, what is S_{naught}? I will be coming back in a moment—epsilon cubed.

So, S_{naught} is the specific surface area of the particles per unit volume of the solid particles. So, that is defined or denoted by the Snaughts. Now, this delta P_c over here, this is denoting the pressure across the cake. So, c is the cake. So, filter cake, c is denoting as a cake.

Now, why negative is provided? Pressure is so, here we have a let us say P_1 and we do not know here we have P_2 and maybe here we have P_3. So, total pressure drop across this one P_1 minus P_3 right, but this is the sum of P_1 minus P_2 plus P_2 minus P_3. So, P_1 is higher than P_2 ok. That means flow is occurring in this direction, the pressure is dropping.

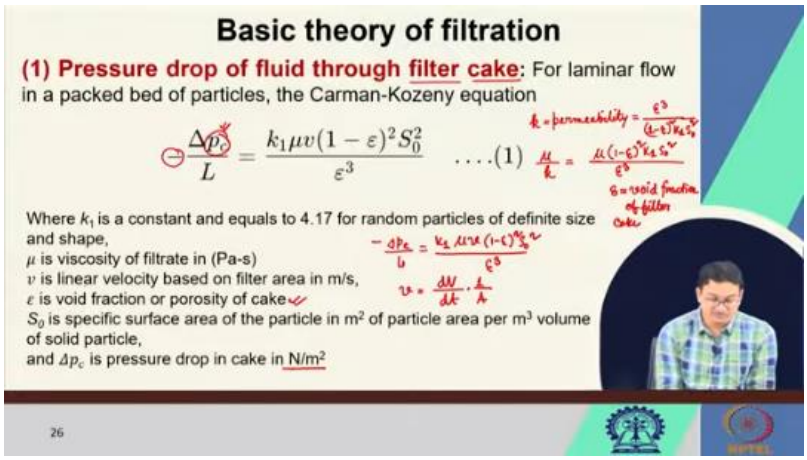


The flow is occurred in this direction, in the direction of where the pressure is you know going down so that's why the negative sign is given over here all right so if you do it so delta P_c by l therefore you will get this if you put this one you will get k_1 mu v_1 minus epsilon square s not square divided by epsilon cube okay so that's the thing we have so far um Now, you imagine, so what is epsilon? This one, epsilon is the void fraction of filter cake, void fraction of the filter cake. That means the void plus solid, epsilon plus let us say solid is C gives equals to 1.



So, that is the one we have so far. Now, what will we do? So, what is V? V is dV/dt. So, V is the capital V, which is the volume of the filtrate multiplied by 1/A. A is the filter area.

Delta P_c is the pressure drop in Pascal (Newton per meter squared). The void fraction or porosity of the cake means the volume of void divided by the volume of the cake. v is the linear velocity based on the filter area in meters per second, and mu is the viscosity of the filtrate. Now, what will we do? We will try to derive.

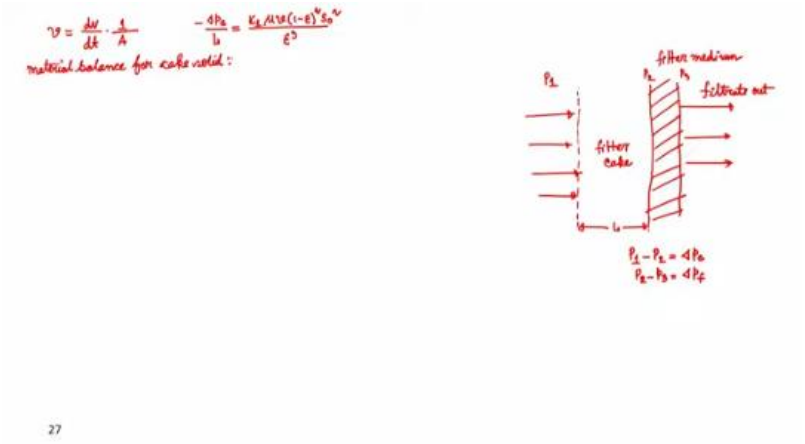


So, this is the knowledge we have so far for the cake. Now, what will we do? We will try to derive the basic filtration equation and the overall pressure drop. So, let us say this is our filter medium. Maybe I will draw here. Okay, I will draw here, which will give us... So, this is our filter medium.

Here, we are having cake formation. So, let us say this is L, this is filter cake. So, slurry flow occurs in this direction. Here we have filtered out. P_1, let us say here it is P_2, and here let us say P_3, and let us say P_1 minus P_2 equals to pressure drop across the cake, and then P_2 minus P_3 is pressure drop across the filter medium, ok. Let us define this way, ok.

Now, what we will do? So, v is the velocity of the liquid, which can be written or filtered velocity is dv/dt divided by 1/A. And what we have so far is minus delta P_c by L, which equals to K_1. I will just go back: K_1 μv, K_1 μv_1 minus epsilon square is not square divided by epsilon cube. I hope I am right: μv. Now, what we will do is we will make a solid balance across the filter cake, material balance for the cake solid. So, material balance for cake solid.

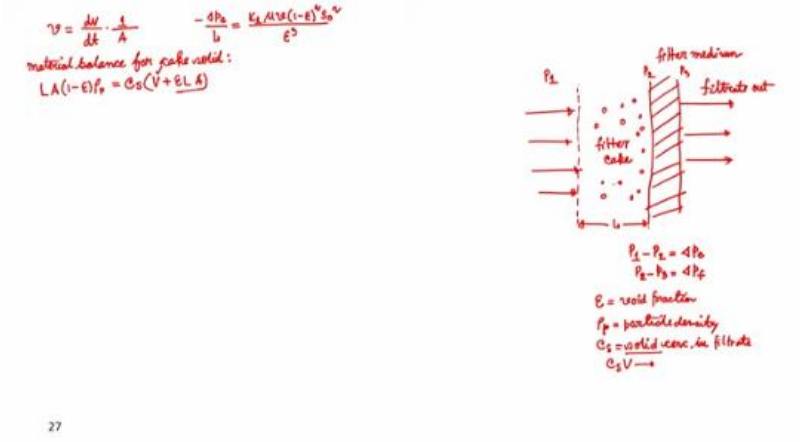
So, what we have, let us try to understand, ok? Let us try to understand. So, we have the whole thing over here. The epsilon is the porosity, ok. So, the remaining part is our solid, ok. The remaining part is the solid. So, can we write that? Let us say L A, that means filter area multiplied by the thickness of the filter, it gives us the volume. Multiplied by 1 minus epsilon, what it gives us is that the solid part multiplied by ρ P. So, ρ P is let us say void fraction, ρ is the solid density or particle density, say particle density.



Rho P is the solid density or particle density, say particle density. Equals to, you will define in a moment this term C_s multiplied by capital V. I will explain this one. Epsilon multiplied by L A. C_s is the solid concentration in filtrate. That means, you know, mass of solid per meter cube of filtrate. So, V is our filtrate volume. So that means it makes sense, C_s into V.

It gives us, you know, per unit filtered volume we have the solid concentration. This will give us the solid. Now, this part also has been added. Why? See, the porous part, the voids, it also traps some amount of liquid over here. And liquid also has some solid particles. So, we have to take these things into account. Although this value is very small, we can neglect it, but we have to take these things into account.

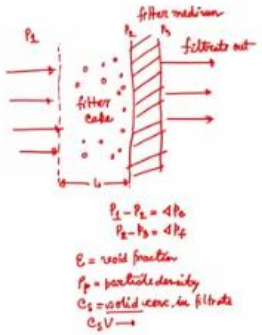
So, that is why C_s V plus epsilon L multiplied by this one can be neglected as it is very small. So, we have done our material balance. Now, we will use this information of the material balance for our next part of our class for deriving the total pressure drop equation. So, we will stop here today.



$v = \frac{dV}{dt} \cdot \frac{1}{A}$ $\quad -\frac{\Delta P_c}{L} = \frac{K_c \mu v (1-\varepsilon)^2 S_0^2}{\varepsilon^3}$

material balance for cake solid:

$LA(1-\varepsilon)\rho_p = C_s(V + \varepsilon L A)$ → can be neglected as it is very small



$P_1 - P_2 = \Delta P_c$

$P_2 - P_3 = \Delta P_f$

ε = void fraction

ρ_p = particle density

C_s = solid conc. in filtrate

$C_s V \longrightarrow$

27

Thank you so much.