Energy Efficiency, Acoustics & Daylighting in building
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 29
Ventilation

So, I think we were looking at natural ventilation another day.

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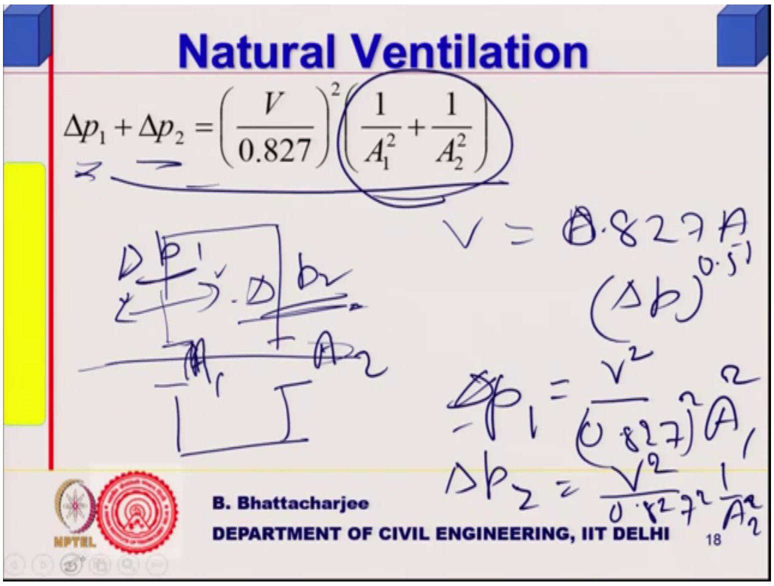

We came to the conclusion when you have two windows or two openings in series that means I have something like you know I have something like this one opening somewhere here, one opening somewhere there, right. There is one opening here, one opening there and area is A 1, this area is A 2, right. So, the delta p 1 is here, delta p 2 is there, that is right. So, sum total of this is from the same formula because we had 0.827 delta p to the power half v was know I mean flow was equals to A. Remember that A into 0.827 A into delta p to the power 0.5, I think that is what it was, all right.

So, if we now look back, now I have got pressures can be summed up because yep you know pressure here, it is different than the pressure inside and inside pressure we are assuming it is constant and from inside pressure to this one. So, delta p 2 is the pressure difference here; delta p 1 is the pressure difference here. The flows through them are same. Whatever comes in must be going out through the same opening. So, we same and therefore, I can write delta p 1 which will be equals to A 1, you know delta p 1 will be equals to v square that is meter cube per second flow square 0.827 square again and A 1 square. Similarly, delta p 2 could be written in the same manner v 2 square divided by 0.827 square 1 over A 2 square. So, if I sum this up, I get something like this. That is what we have seen in the last class, right.

So, therefore, if I am looking for the flow through this space, the room then I can assume equivalent area as this 1 by A square you know 2 by a square something like that I can assume equivalent area. So, how do I do that? That is what we are looking at in the last class, right. So, how do I do that?

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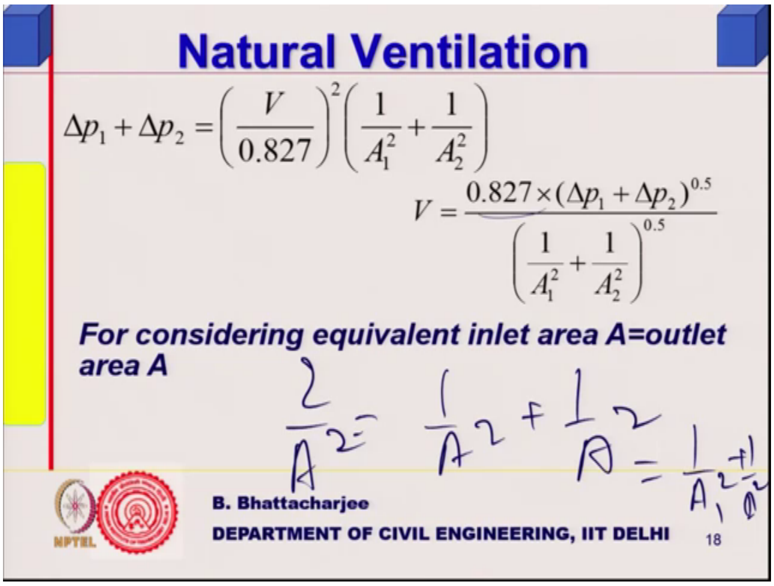

Next stage is write v in terms of rest of the things we in terms of rest of the things. So, then this becomes you know 1 over this. I can write simplify it would be written as this. I can write an equivalent area of A if I assume on inlet as well as outlet same, then it will be 1 by A square plus 1 by A square again, right. So, it is 2 by s square which is equals to them from this formula 1 by A 1 square plus 1 by A 2 square.

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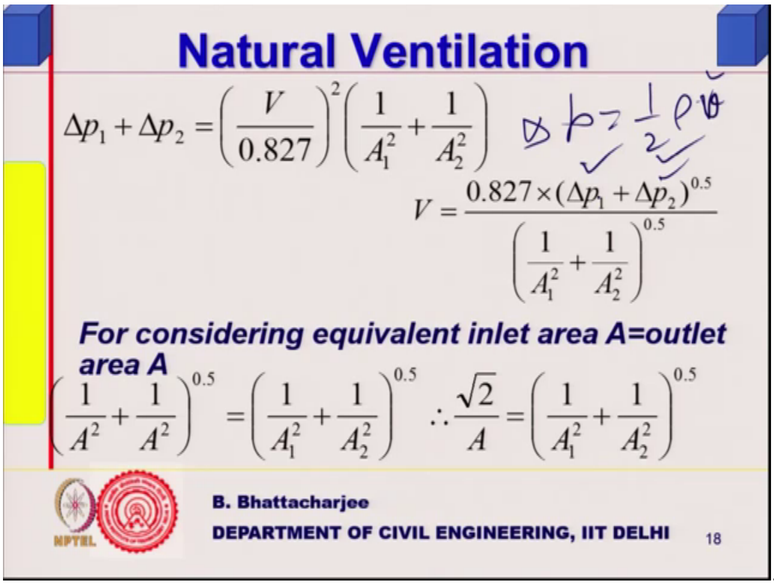

So, I can write an equivalent area A for the inlet as well as for the outlet and this A should be given as under root 2 by A is equals to this or 2 by s square is equals to 1 by A 1 square p 1. So, inlet or outlet where areas are different, then I can find out an equivalent area of inlet which is equals to arc length which is given by this formula, alright.

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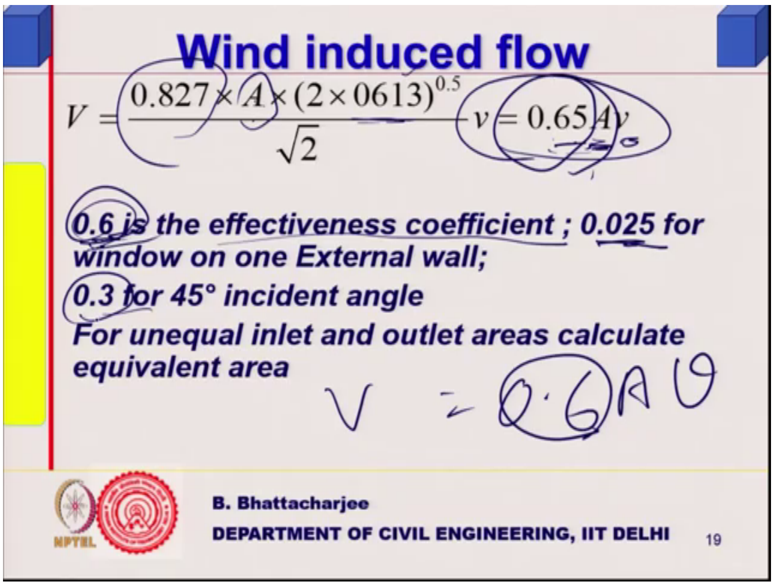

So, I can then calculate out the flow. Now, flow would be simply 0.827 A, right and pressure is taken as delta p. We are taking let us say delta p 1 delta. P 1 pressure can be written as half rho v square. You know this is the rho part of it comes to this one. You know v, I am just replacing. Supposing I write. So, v is delta p 1 delta p 2. Express them delta p 1 in terms of velocity express it in terms of velocity. So, delta p 1 should be equals to some relationship v square velocity square velocity square at the inlet. Similarly this will be related to velocity square at the outlet flow is same velocity square at the outlet. Now, half rho is 0.613.

So, because 1.2 was the density is the density of air. So, if you take it, it is close to 0.613. That is what we are doing. So, 0.613 is this and twice of delta p 1 and delta p 2, there are two of them. So, 2 into 0.63 area if I assume equal area, then root 2 will come here because equivalent area of inlet just multiplying with the inlet area. So, then this term comes out to be roughly around 0.065 Av. You know point v is the velocity and this is a velocity outside the air velocity. We are assuming outside air velocity v 0 somewhere in the open. If I know it just I can multiply that by the area of inlet into some coefficient. This coefficient is taken to be 0.6 although you know by my simple calculation as if the v is same as outside velocity, right.

So, it comes out to be roughly around 0.65 Av. So, c is 0.6 is called coefficient of effectiveness. So, the flow is given as v meter cube per second is given as 0.6 A into velocity outside this constant something you know I mean it is some constant into A into v. That is what we are showing the value that is taken is 0.6 and it is called coefficient of effectiveness. When you have windows both at the windward direction as well as leeward direction that means, you have cross ventilation that is what we have you know, so 0.025 on only one place, only one external one not cross ventilation only one.

So, these are empirical by enlarge and it is also taken to be 0.3. These values are taken point to be 0.3 for 45 degree angle of incidence for 45 resistors on normal incidence. This for photo editing rule for unlike an equal inlet and outlet we can actually calculate the equivalent area. There we have not compromised. We have only not compromise I mean say no empirical values, but this coefficient is somewhat empirical coefficient is empirical.

Student: The way we are using.

Yes because you see this is A v is the velocity outside and v exactly at the window will not be same. So, this is what is used. This is empirical, but it is somewhat close to this.

You can see that it is not very far off from this. I mean the basis is clear. Basis is somewhat clear.

So, 0.6 Av is what we want and we used 0.3. When it is angle is 45 degree, again these are somewhat empirical and for a nickel inlet and outlets, you can use this formula you know. So, in practice 0.6 Av normal incident to in and for you know this is for only inlet. This window only here or it is locked the suction here.

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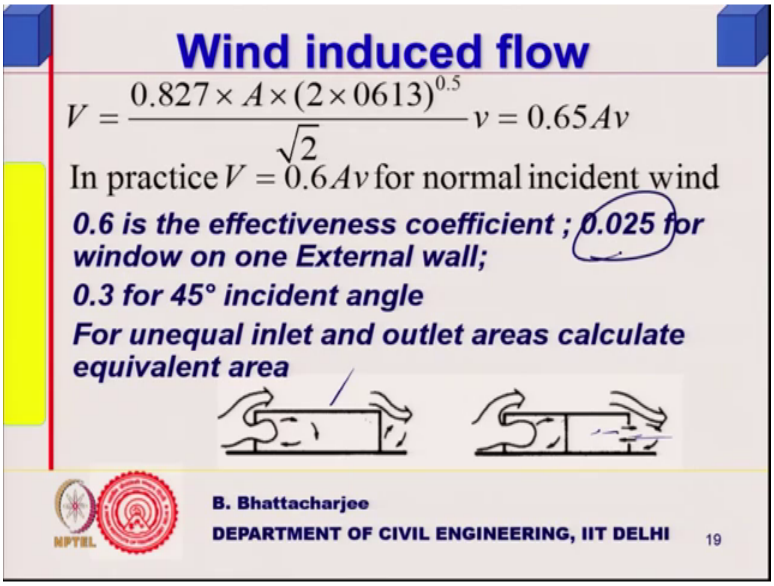

So, there will be some eddies coming in, then this becomes 0.025. So, this is what is used in practice. A quick calculation you can do on this basis, but if you want a full analysis of a large area and things like that today of course, you have got all computational fluid dynamics software and through it you can do it.

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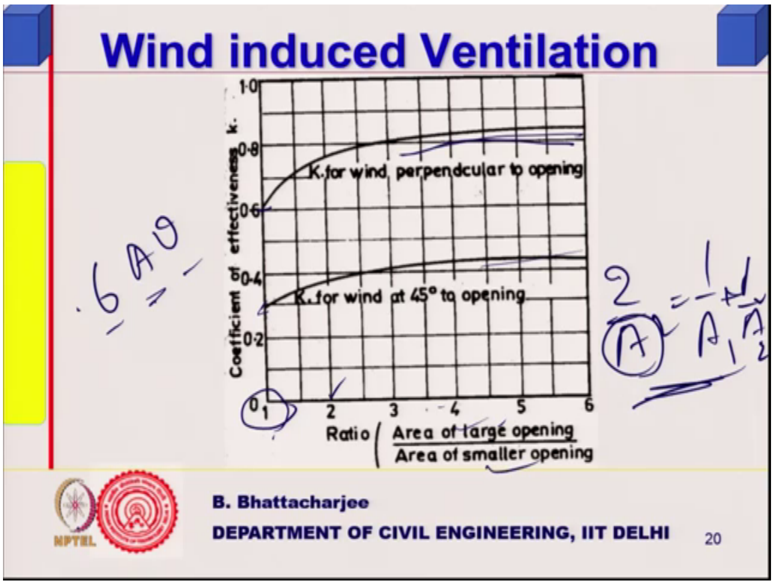

The sp 41 gives you two curves for this k coefficient of effectiveness for ratio of area of large opening to ratio of area of smaller opening.

If they are all same, both are same wrote openings in inlet and outlet, they are same that is equals to 1. Then, this is for normal wind, right. For one, it is 0.6 and for other values, you know sit one is to two area of large opening is twice the area of that, then you got to find it out by this formula A square is equals to 1 by A 1 square plus 1 by A 2 square. You can find out with this formula or you can use this curve where the coefficient of effectiveness is actually modified through this formula only and you are taking the area of the smaller opening here.

Actually area you are taking this area when you take this for these coefficients, we need not bother about this coefficient, but this is what exists in sp 41. It gives you coefficient of effectiveness depending upon area of large opening to area of smaller opening because equivalent area will change. So, you take 0.6 into smaller opening multiplied by velocity outside, right. Same thing you can do here.

So, you can do the same thing. You can otherwise use this and find out you need not use you know. So, find out an equivalent area and use 0.6 A v and 0.6 A v. So, if you calculate the equivalent area by this, then you need not look at this coefficient 0.6 into equivalent area into velocity you can use, but it also gives us p 41 gives you a curve. So, that one can use also for 45 degree. This was 0.3 and then, this is higher, right. So, that is how we can find out flow due to wind s driving force flow due to wind s driving force, right.

Now, we can look at the thermal force take effect wind s driving force we have seen. So, all that I got to do is to start with just let us look at it a little bit more.

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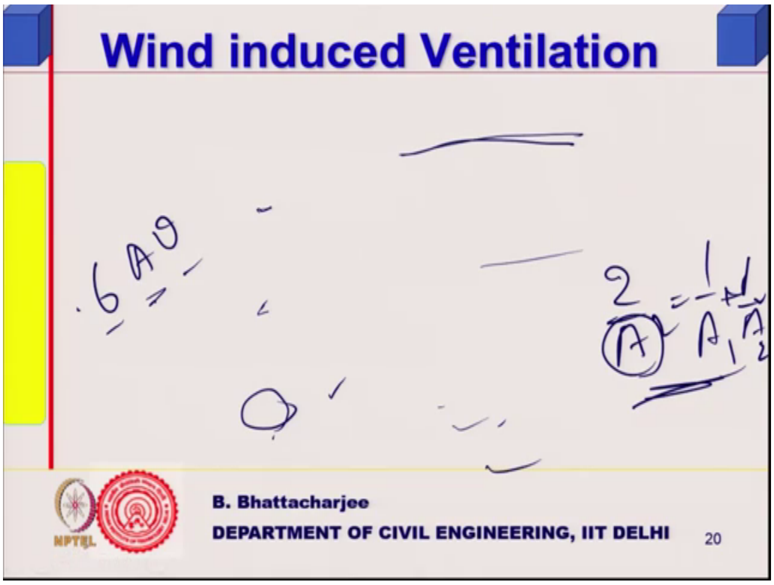

All that I got to do is first identify you know whatever your space is, whatever it is, whatever the size is, whatever the size and shape direction of the wind is known.

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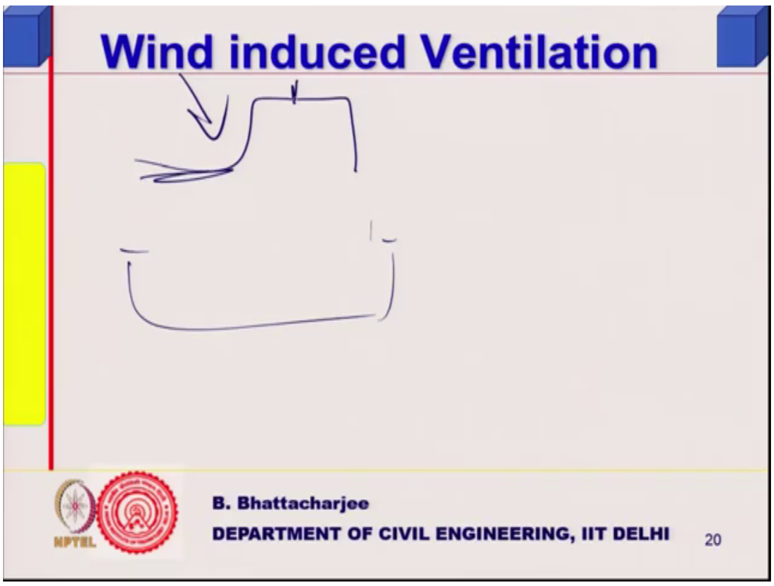

So far in this case, let us say this is and I am bothered about only two angles either normal or 45 degree. In both cases, you can find out the equivalent area using that formula 2 by A square is equals to 1 by A1 square plus 1 by A2 square and use that formula multiplied by the v outside into either 0.3 for 45 degree angle of incidence, 0.6 for normal, right.

Now, all you got to do is, first find out the windows or openings located in that window, a direction that will be inlet and restaurant will be on the leader. There outlet you can sum up these areas because we have seen when they are in parallel, you can sum of the areas. When they are in series, then you were to find it out by this formula 2 by A square. A square is equals to 1 by A1 square plus 1 by A2 square. So, all windward areas you can sum up their inlet, all leeward areas you can sum up their outlets in a given space, right. So, that is what you can do and find it out and then, calculate out what will be in velocity inside.

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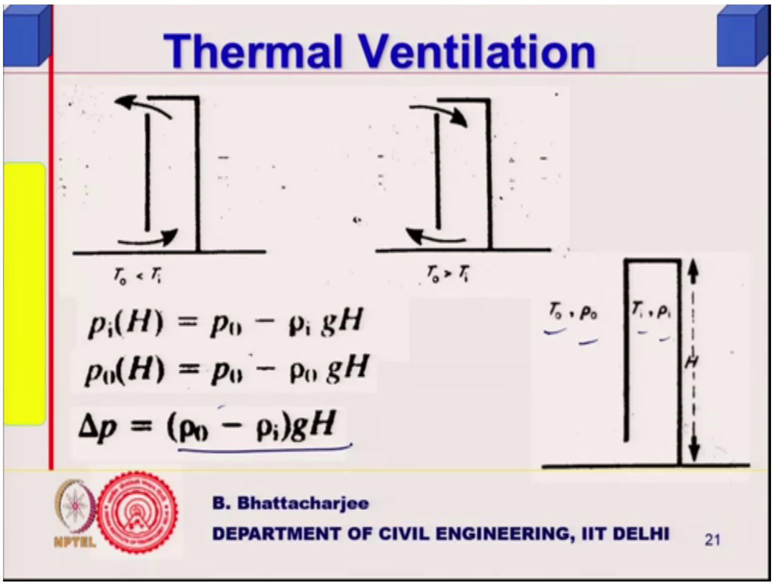

Now, if you look at thermal, thermal is something like this you see if the outside temperature is greater than inside temperature, right.

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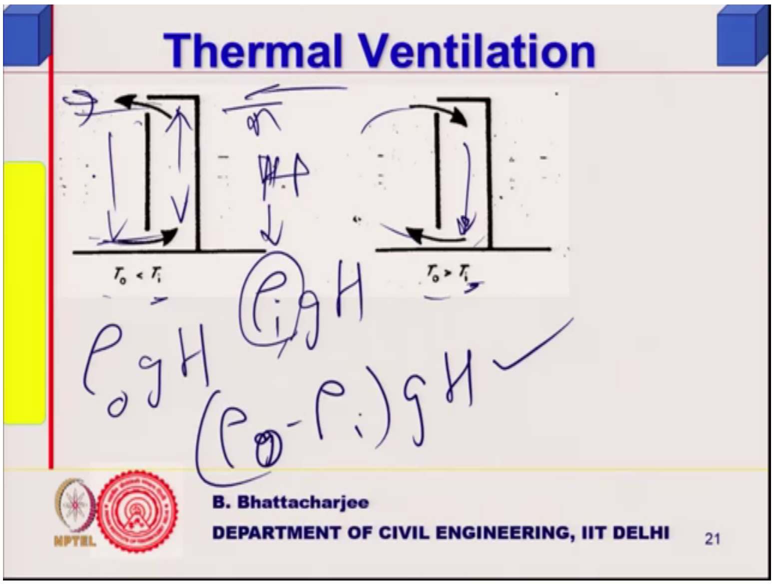

Now, let h s say this height is capital H. This actually book uses capital H. That is why I am using capital H. I can use even small h whichever is convenient, right. You know center to center of this opening height is h, then what is the pressure here rho inside g h and what is the pressure here, rho outside g h. If the temperatures are different, say this case inside temperature is greater which means density will be less.

So, this will be less. So, I will have rho 0 minus rho might into g into 8. That will be driving the air movement and going from this direction because pressure here is more. So, it will cause air to move inside, it will cause they are to move inside and pressure here is high, it will cause the air to you know. So, this circulation has to continue. If outside temperature is greater, then pressure inside will be more, right because the density is more there. You know this temperature is lower.

So, density is inversely proportional to temperature. So, pressure here will be more. So, it will cause flow like this. So, this is what is take effect. So, it is a function of h. It is a function of height. You do not realize this if unless the height is sufficiently large I mean single storey building you may not have much of an effect, there a little bit effect, but if you have a shaft, if you wish I know there you might find it staircase shaft or somewhere or tall buildings, you might see it actually and this is without any wind, not windy estate or window post.

Supposing my direction of the wind is something like this, this would be opposed by this. So, actually this will get reduced and if the direction of the wind is like that maybe it will help the cause. So, you have to see how they act actually. Anyway let us find out some quantified values related to this. So, this is how it is.

So, that is what I am saying T 0 rho 0 T i. Rho i h is the height and rho i h is equal to rho 0 is the atmospheric pressure outside minus rho i gh and inside pressure will be like this and outside pressure will be given by same you know atmospheric pressure, pressure minus this, this 1 rho 0 hs. So, if I find out the difference delta p, this will be given by simply this formula. Depending upon where the temperature is higher, flow direction will vary and this is the pressure difference which is causing the flow pressure, difference which is causing the, no this is a pressure difference which is causing the flow, right. This is a pressure difference which is causing the flow.

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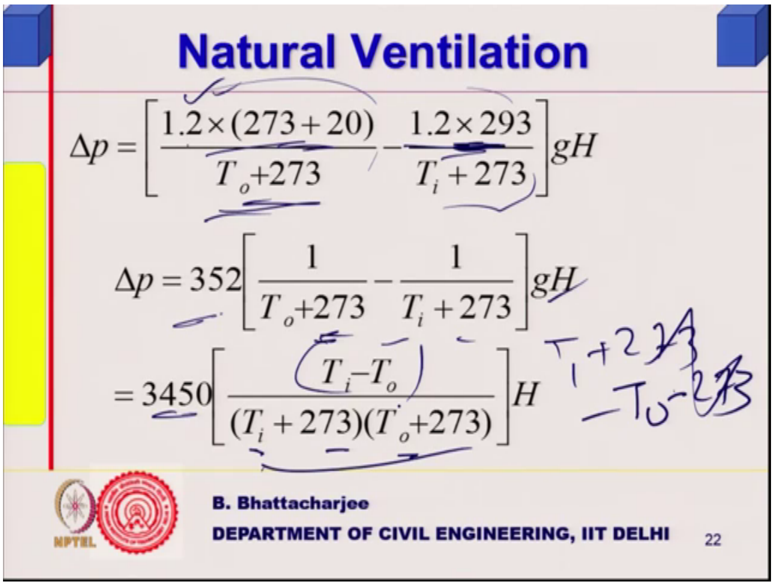

So, now delta p remember we already had, ok. So, the density we can find out in this manner density is 1.2 to 7320. Remember that 20 degree centigrate we are taking roughly about 1.2 and at any temperature it will be T 0 plus 273 rho at 20 into T rho 1 T 1 divided by T2. This is the density and inside this is you know this is a density, right. So, inside density is this as a function of temperature and outside is like that into g into h. So, this is 352. This value is 352. You calculate out, this will come out to be 352. So, this will come out something like this 352 multiplied by again g you multiplied by g.

So, you get 3450 T i minus T naught. You know T i minus T naught you can find out, you take product of this. So, it will come out to be T i minus T naught because 273 will cancel out. I mean it is actually if I take T i 273 into T 0, 273 this part will be T i plus 273 minus T naught minus 273. So, this will cancel out.

So, I will be left with this temperature difference and this I can take somewhat average temperature actually this second you know this one I can take an average temperature and a fixed value. So, I can show that it is a function of delta T, so that I can show an average temperature that we come across.

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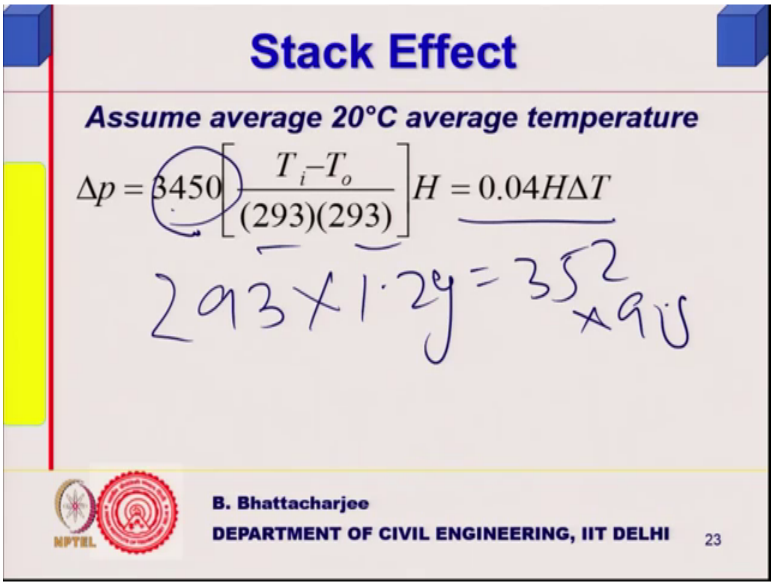

So, taking a value of T, the 20 degree centigrade average temperature, then this we take as to 93 to 98 roughly or you know like some values like that this will turn out to this was 3450. How? It is because 293 into 1.2 was 352 x 9.8 g. So, this comes out to be 3454 and this is approximately this comes out to be 04 h delta T.

So, it is a function of as well as temperature difference inside and outside the difference, a function of height as well as outside temperature difference, right. Outside I mean temperature difference between inside and outside. That is right. So, that is what it is.

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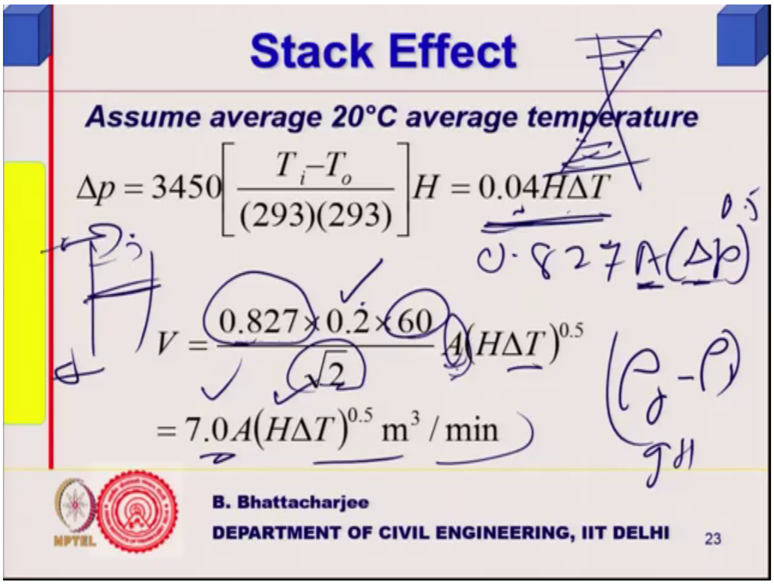

So, if I take this you know if I take this as the delta p, then what would we flow 0.827.

Student: into

Yes, into area and delta T has come already. So, 04 and equivalent area of the inlet and outlet if I take same areas both and like take only one area here, you know this area of inlet which or equivalent area of inlet and outlet, there may be different inlet area, there may be different, but I take an equivalent area, then root 2 will come here. Root will come here and 0.4 under root is 0.2 because delta p to the power half remember it was you know 0.827 A into delta p to the power 1. I mean here it will be you know delta p is driving the whole total from delta p 1 plus delta p 2 everything and delta p 1 plus delta p 2, it is this driving the full flow.

So, area therefore I am taking equivalent area and this was this must have been if I want to find out meter cube per minute multiplied by 60 meter cube per minute multiplied by 60 and this you will find approximately comes out to be 7.0 A h delta T to the power 0.5 meter cube per minute. You know this 0.2 comes because under root of 0.0 for delta p to the power of delta p 1 plus delta p 2 equivalent complete, I have taken and A under root 2 is an equivalent area where A is the equivalent area of in electrical outlet, equivalent area of inlet. Supposing inlet and outlet areas are different, then you resort to that formula that you are good. So, this is what it is and this comes out two points.

So, you will find this formula in the code sp 41. You will find this formula in the code, right. So, h is the height difference between the inlet and outlet center, yeah. Now, supposing you have several of them, number of them at different levels, then there is something called a neutral plane. Neutral plane is one where rho minus rho i, there would be into g h into g h is equal to you know this is same, this is equals to 0. There will be some height you see. If the height difference if you calculate from depending upon some height from the neutral plane I mean you can take it h 1 and h 2 downward h 1 up from a neutral plane assuming 0 somewhere, the pressure will be because at the bottom, it is flowing along and the bottom, it is flowing along.

Let us say flowing along this direction top it is coming along this direction. That means, the pressure here is higher than this somewhere the pressure is 0. That is called neutral plane. Anything above will act like inlet, anything down below will act like outlet. Neutral plane is where this is 0. So, you can find out supposing I can do a little bit more complicated thing, in fact I may not complicate it. Change your h value not from the bottom, but take from the neutral plane.

So, pressure at the neutral plane will be yeah it has to be 0. So, pressure will be equals to inside density into that h minus the outside and density into that age you know equivalent you can find out and if you go below, then this will be minus h. It will be minus. So, accordingly you can calculate out a neutral plane is 1 where or it y you can just assume that linearly it is varying from top to the bottom and it was you know like it is symmetrical if there is no wind, it will be symmetrical. Actually the pressure would be symmetrically varying, pressure will be symmetrically varying, pressure will be symmetrically varying.

So, at the center height you can take approximately as a neutral plane. Anything above will be either inlet or outlet corresponding one and the below that would be you know corresponding if it is inlet up or outlet down. So, you can actually calculate out from this one if there are a number of them actually and you can add them up all in. Let us you can add them up all outlets. You can add them up in the same manner as you have done, but here pressure are different, heights are different. So, you actually have to the you know pressure that delta p will be different in each cases. So, delta you know you can calculate them or the flow through similar height will be same.

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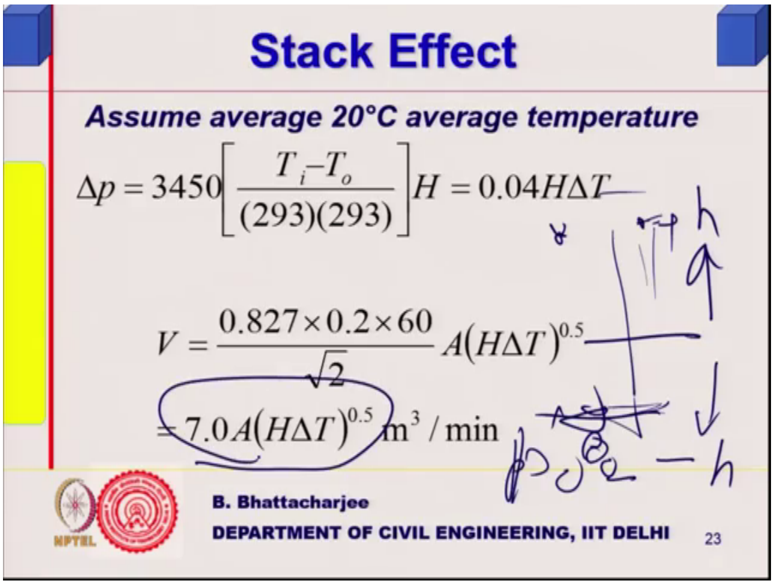

If there is a flow here, you can actually use Bernoullis equation pressure at that height. You know the pressure here rho 0 plus I mean p 0 atmospheric plays pressure p 0 minus from you know supposing p 0 is somewhere away. So, you can actually resort to Bernoullis equation. The pressure head velocity head, they must be same. So, if you quit, you can obtain it from Bernoullis equation. We have not put it into the equation because that was not required.

For our purpose, we are trying to calculate over only the quantity of flow, but you want to find out above neutral plane. You take h 1 below neutral plane, you take my mean h below neutral plane, you take minus h, right. You can assume neutral plane here, h varying positively here minus h along this direction plus h along this direction, then equate at you know basically pressure at velocity at and datum head sum total remains constant from Bernoullis equation. So, from that actually we can find out if we want to, but we do not want to do that all. Our interest was delta p because delta p to the power 0.5 is what is our into this. So, you can actually find it out actually.

You can find out, but at the moment we are not really what result you know. Basically if there is some flow from here, velocity here, the velocity there has to be some velocity up there also because the flow has to continue. So, you can find out inside velocity. Outside velocity you can find out the pressure outside which is p zert. Let us see atmospheric pressure, right and then, pressure here would be p 0 minus something plus the velocity.

So, you can actually find it out how much the velocity would be at even point, but we for our purpose you are not interested. We are interested in deriving out this formula which you find in the code which you find the code. So, basis of the formula in the code I just want to tell.

Student: How will you provide?

While if you deliberately want to do it that is like wind tower, you know that we said that middle east they use it quite a bit. Supposing you provide a tower at the center of the building. Remember I showed you that passive, so that you know you can provide it, but I mean providing that would be not an easy job to do in a functional building. The functional building you can only calculate out the effect of it right, but if you want to deliberately make use of it, you have to provide the tower something like wind tower that is used in Middle East or some sort of passive tower actually provide.

Stack effect, no it is a temperature difference inside and outside and also, the height. Height is the main important.

Student: Height.

No no, if in a tall building supposing I take in a tall multi storey building you know and let us say it is not conditioned area. You want to approximately find out let us say you have a lift shaft or a shaft, where there are openings from outside just to that like fire lift, encased fire lift and there be heat exchange to that or similar sort of situation. Even not in case supposing I have openings which is not closing, right lift and staircase shaft, there also this you can use, but this becomes more useful if you are dealing with fire because there the temperature difference is too large and actually where if there is a fire at a given floor, the smoke will have a tendency to go upward.

It would you know whole thing changes and even within a small compartment fire modeling is done based on basic concepts of this, similar thing because top of the window half even in the same window, top half through, top of hot gases will go out from bottom half, fresh oxygen will come in. So, you know this is basically physical understanding of the movement of air due to what we call thermal siphoning and a thermal effect basically. Because of thermal effect that is not really and I hope my purpose was to look into the formula which you will find in the code which will say the stack effect is now you see if h is small and temperature difference is small, this affect be negligibly small.

Next if you want to use in single storey building, it may not be much. It will not be much because delta T will not be very large in one. We meet climate where the ventilation is required most. So, realizing this is not very easy un single story building or height difference at best will be 3 meters, 3.5 meters not really much. So, that is ok, but we must understand conceptually and then, even it is useful or not that we insulator right as in as you know, since take effect involved equal inlet and outlet area. So, that is what we say fine.

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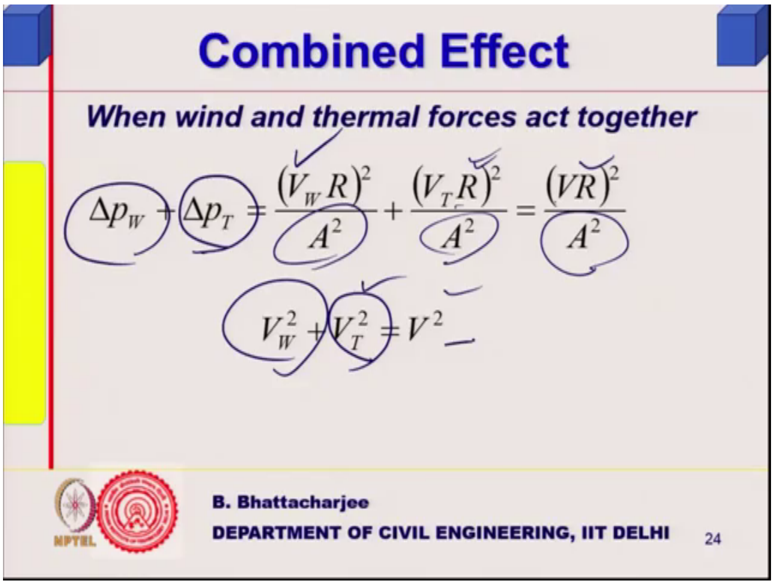

Now, when I have combined and each helping each other, the flow due to wind direction of wind is such that it helps the stake effect, right. Both are there mean why not have both together, but if you have, then delta pw to in the effect plus delta p pressure difference. If they are helping each other, then I will have flow due to wind effect into some resistance by us s square. That is what we said you know all constant we are putting.

So, I can write in two equivalent areas. Area is same. Supposing area is same. So, it would be written like this you know delta p T, yeah. It would be, it can be written like this because the resistance is same. So, v can be written as, v square can be written as vw square plus v T square because pressures are added up. So, flow is flow square can be added up cb is proportional to flow v meter cube per second is proportional to delta p to the power 0.5. So, if I am adding up the pressure, two pressures are adding up, then v square will be added up. So, v 1 square plus v thermal square is equals to v square equivalent will be sum total of the square. Squares will be added up. So, that is the sum total of. That is some go to do. That is the sum good, right. So, any question if you have more will answer, then we go to looking at thermal comfort ventilation.