Energy Efficiency, Acoustics & Daylighting in building

Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 30
Comfort Ventilation

So now we will follow up with comfort ventilation, right? What was comfort ventilation? Local velocities, at some level of the human level, which will provide evaporation or removal of heat by convection or by evaporation loss you know. So, sweat generated would actually minimum, so that requires air velocity. And now, we can find out desirable air velocity, knowing the temperature and relative humidity. How? Remember TSI and TSI formula was dry bulb temperature, wet bulb temperature

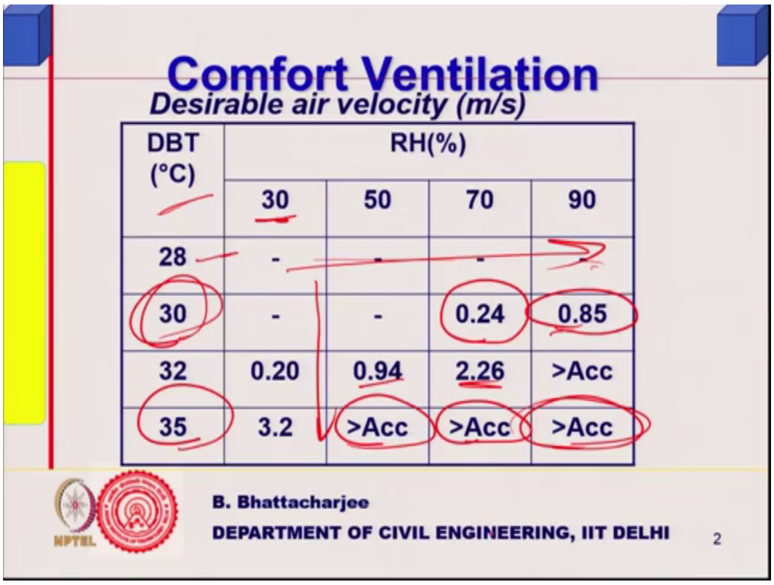
Student: Minus.

Minus 2 under root.

Student: (Refer Time: 01:03).

Right. So, therefore, I, if I know the TSI comfort range, so, either put it 230 or 34 is tolerable, 30 and you know, the dry bulb temperature and either you know, the relative humidity or wet bulb temperature. So, correspondingly what is the desirable velocity you can calculate out and this has been calculated from this one from you know, from TSI values. Say, when dry bulb temperature is 30, sorry 30 – 28, relative humidity; you do not really require because 28 even at 90 percent additional air velocity is required, not required, but if it is 30 TSI. I am not talking about, you know dry bulb temperature is 30 from TSI am calculating back. So, velocity of 0.24 meter square is fine, meter per second is fine, 0.85 meter.

(Refer Slide Time: 01:27)

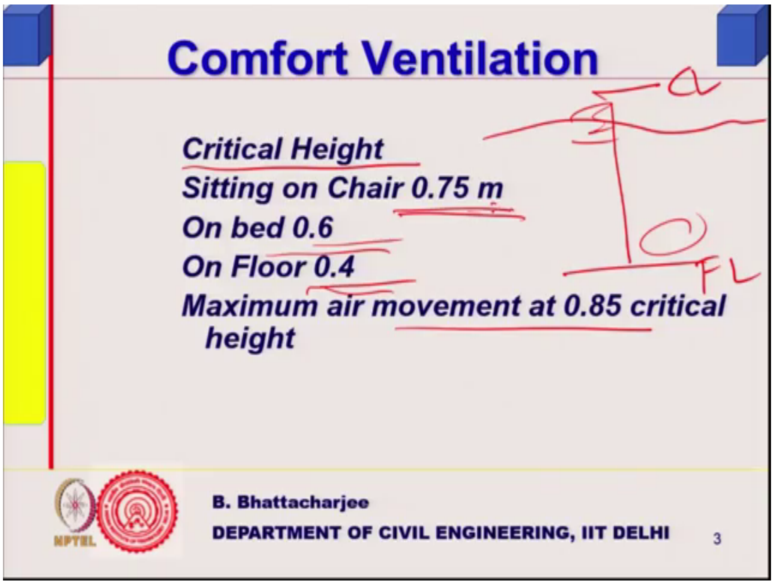


DBT (°C)	RH(%)			
	30	50	70	90
28	-	-	-	-
30	-	-	0.24	0.85
32	0.20	0.94	2.26	>Acc
35	3.2	>Acc	>Acc	>Acc

So, as the relative humidity increases, I need higher velocity. Desirable velocity is higher as the temperature increases. Desirable velocity is higher and you know, this, I mean, this is 0.2425 etc, etc. This, you can actually cannot achieve. It is too high you know, 35 degree dry bulb temperature 90 percent relative humidity beyond acceptable limit beyond acceptable limit actually.

There are other aspects also. If your velocity is too high, you start feeling a kind of a discomfort also because you know, supposing you are standing on a gust or you know, skin tends to be to dry papers fly away. So, all this kind of discomfort is there. So, this is 35 - 30 percent relative humidity, 35. Other you know, you have to provide other means. You have to provide other means right? Maybe local fan even, but this velocity should not be too high. So, some partial, but other means should be useless. So, this desirable air velocity can be obtained.

(Refer Slide Time: 03:16)

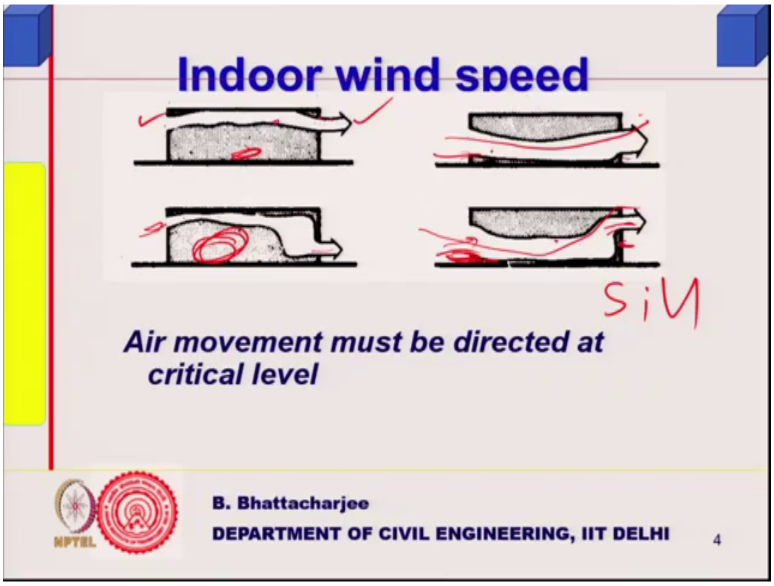


Second issue is critical height. Where do you want the velocity, because velocity at all level may not be same? This is the flow level. Let us say, this is the ceiling level. Now, you want velocity at certain level. Supposing, I have openings at this level - both inlet and outlet. Here, we will enter like this and go away. Velocity still here will be 0, but you will have still meter cube per second flow and we still high, but that does not mean you will have comfortable situation. You know, comfort ventilation velocity may not be higher that desirable level.

What you need is the critical height, is sitting on the chair is 0.75 meter. It is actually the hair level because if you can remove the heat from the hair level, human hair level that that gives you more comfortable, you know. The air, I mean the blood circulation to the brain. So, head has to be an even you might see that whenever you are jogging or doing something, you have a lot of sweat, here. It so, naturally try to sitting comfortable is 0.75 meter level. You know computer should be kept, CPU should be kept cool. So, that is very important.

On bed; obviously, somebody is lying 0.6 and on floor sitting children, school children you know, like or like necessary level children not sitting on floor, but small chairs and all that. So, that is around 0.4 levels. So, maximum air movement should be at 0.85 critical height levels. 0.85 percent of the critical height level, so, you can see that this is you know, to the floor not too high. So, that is critical height. So, comfort velocity should be high there, flow can be there through anywhere, which will remove the heat, provide even possibly fresh air, because you know, like if it is hot air, it will go up and them get out, fresh air supply also (Refer Time: 05:17), but this.

(Refer Slide Time: 05:20).



So, if you provide all opening here, at the top level, actually no velocity there, it is not useful from velocity point of view. But if you provide somewhere, there is a sill height and if you provide somewhere there, then it has a tendency to. So, the sill height is very important. Sill height of around 0.9, 0.75, 0.8; they are good, right? These top level ventilators, they do help in removing some heat, but not necessarily providing higher air velocity at the floor level. If you have something like this opening in that then, is fine, but this will be even shadow this will be shadow areas, this will be shadow areas, this is again fine, inlet here, outlet there.

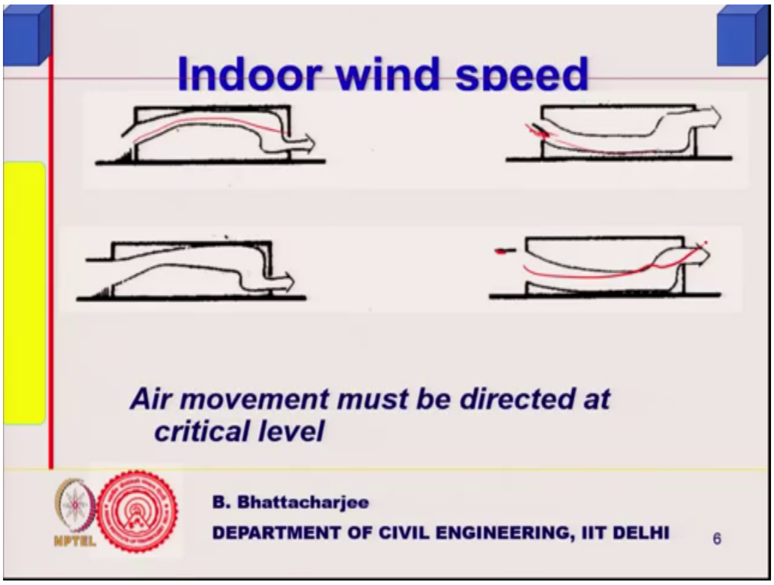
So, height of the ceiling, height sill height is important. I mean sill height is important with respect to floor and air movement must be directed at critical level window sill. Window sill is this, this is the window sill, this is the height you know, the where the window starts so, that height is important or opening like. So, top level ventilation may not may take some heat away, but just alone get those positions would not make much of a sense. But some here, some there, that might make sense because some flow might be, it might spread over the whole high.

If I have 1 in 2, at the lower level and then, there is a small ventilator at the top, on the other side also top I have got one ventilator and a window below, then the flow velocity, everything will be high because it will get direct, you know mixture of these two, combination of these two, then this is more useful because you have increase, an effective opening area, right?

(Refer Slide Time: 07:12).

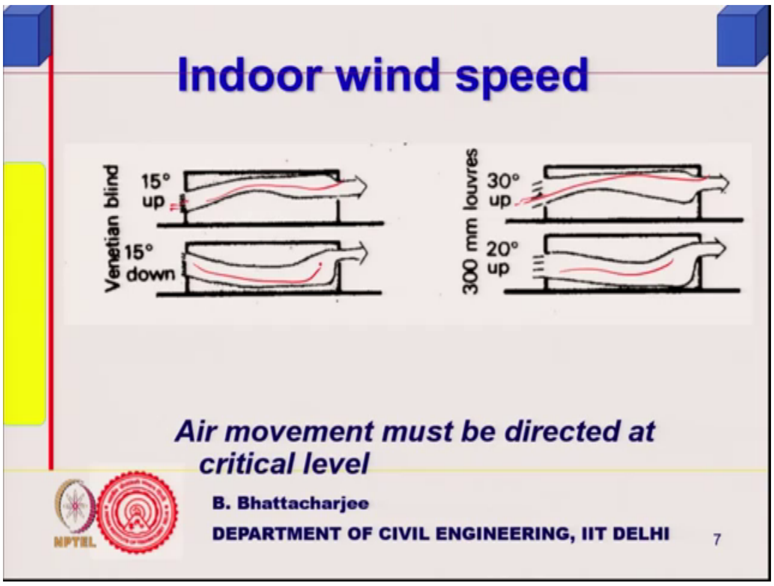
So, in plan if you look at it, if you know it can be something like this, depending upon where it is parapet wall, if it is there, the direct. So, you can use Louvers to direct air. Movement must be directed at critical level as I said and if you have Louvers so, there could be different varieties of flow, actually there will be some shadow portion depending upon how you have located.

(Refer Slide Time: 07:34).



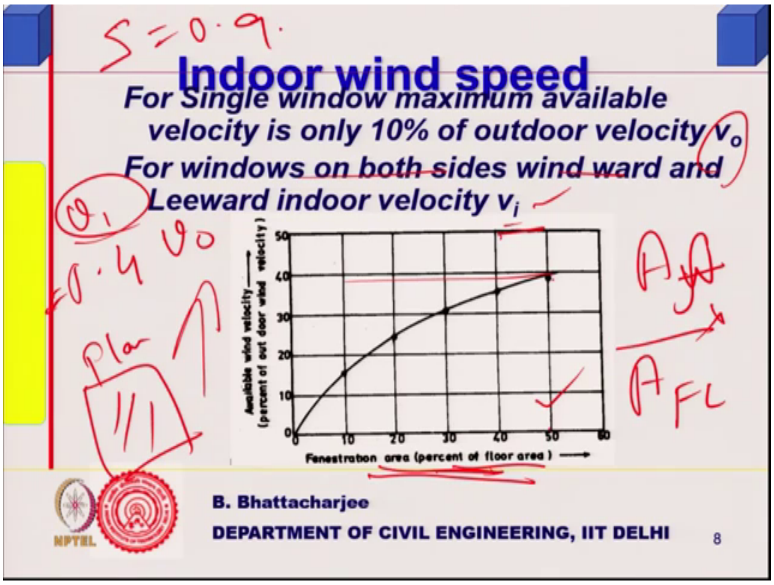
Those windows and some more diagrams showing the same. If I have a Louver, otherwise it was flowing like this. Suppose I have put a horizontal Louver; you know horizontal Louver or the one I was talking about rotating one, these were, they are actually, earlier days you would have seen the windows or venetian blind. You can actually close in horizontal, you know. It can open and close, but supposing I have something in the horizontal plane, similar one. They will direct the wind if it is in this inclination, then it will directed. If it is like this, the sunshade with some opening, it will direct like this. So, they can be utilized to direct.

(Refer Slide Time: 08:12)



Similarly, you have got a lot of fins, here, horizontal fins up to 15 degree up keeping, 15 degree up, 30 degree up. So, if it is inclined like this, they will direct upward. If it is 20 degree, it is something like this - 15 degree down, then put it down. So, depending upon the angle of those fins they can direct.

(Refer Slide Time: 08:35)



Right. So for single window, maximum available velocity is only 10 percent of outdoor velocity. For single window, maximum available velocity is only 10 percent of outdoor velocity 10 percent of outdoor velocity, right – v 0. So, outdoor velocity, we have calling it v0. It is only single window; we will give only 10 percent.

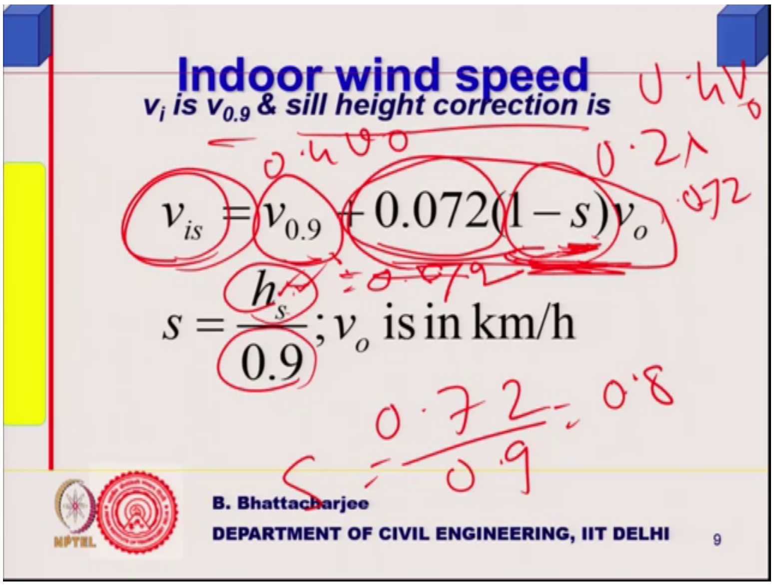
For windows on both sides, windows ardently wind ward and leeward. Let us say, indoor velocity is vi, average indoor air velocity. I am talking about and whenever we have mentioned this, we mean that we rather, we would rather like to keep it. We are talking in terms of the critical 0.85 critical level, the useful level. So, velocity at the useful level actually that is what we should be interested in.

So, this velocity is a function of the fenestration, areas is a part of you know as a percent of floor area versus the available wind velocity. Supposing I have got fenestration area; that means, total opening area all or AF let me call it all fenestration area and floor area is AF floor area, then this is percentage. Now, you can see that if you have for 50 percent then, this goes to about 40 percent v 0; that means your v. You know velocity in your velocity vi; average velocity will be O.4 times outside velocity. A velocity inside will be point for maximum 50 you know floor area you have.

So, this is the floor plan. This is a floor area. The fenestration area at total windows, we know areas, if it is about 50 percent. 40 you know, 50 percent of it. You get about 40 percent velocities. So, you at best outside the air velocity you get only 40, generally, not higher than that. So, that is, this is from good old days internal studies, right? People would have validated the internal studies and safety models, if not one can start, one can do that a little bit and you can actually generate this day set of huge set of curves or similar sort of thing design curves for first design. Detail design can later on, can be done in. So, anywhere if you want to look in the air movement.

So, this was there from internal studies. In fact, this work comes from (Refer Time: 11:05) work this. There in SP 41, SP 41; this comes from SE work. In fact, early works of severe I.

(Refer Slide Time: 11:10)



SP 41 is a, then v 0.9 in hence, then there is a correction for see light correction. Now, when they did this experiment, they kept the sill height. This velocity was measured at sill height level S equals 2.9. Sill height level S equals to 0.9; 0.9 meter was the starting point of the window openings. Starting point of the opening starting point of the fenestration openings, right? So, they started from there and then, if this is different, then they provide suggest a kind of a sill height correction.

So, if we 0.9 is a v, point line is found from the previous diagram. That last one diagram that I give you at any sill height is given by 0.721 minus sill height correction, where sill height correction is given as height of the sill divided by 0.9. So, if this is 0.9 then, this value is one. So, this is actually equals to 0. If this is this, let us say 0.72, then how much this will be? 80 percent 0.8, this will be 0.8. So, this will be, if it is sill height, sill height correction will be 0.2. You know sill height is known as this is equals 2.9, sorry, this is actual 0.72. So, 0.72 divided by 0.9 is equal to how much? It is 0.8.

Student: (Refer Time: 12:49).

Is not it, point it. So, 80 percentage, it is 0.8. So, this becomes 0.2. So 0.2 into 0.072, 0.2 into 0.072, right so, that is what it is. Now, supposing this is more than hs 1 meter, right or 0.99, then this become negative.

Student: Negative.

So, velocity, effectively velocity at my critical level you know, if it is at lower, still it is fine. Anything above is a problem, but then, remembers this is empirical formula. It is not valid for all the ranges.

Student: (Refer Time: 13:27).

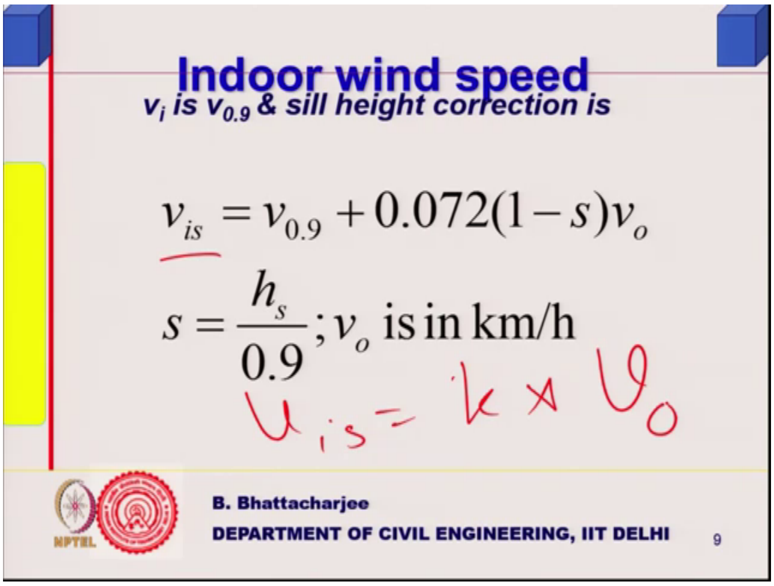
If S is equal to zero, this will have this, will give you 1.072, which is a relatively high value, but that is usually not the case, because you know, infeasible sort of situation. I mean it can be, if it is some people. All people at children are sitting the floor school level. You know those running village, school search it a children. Children are sitting on the floor, but the point is in that case, sill height 0 is, it is not a practical thing. Usually it will not be there.

So, this is this correction gives you anything above it. It would actually, effectively reduce down the velocity for comfort condition because it will not be directed at critical height. So, you can calculate out v is earlier, maximum was 0.4 v0 multiplied. Now, this will be 0.4 v0 and this is also a function of v0. So, you will get something in terms of v0. Again, you will get something in terms of v0 again.

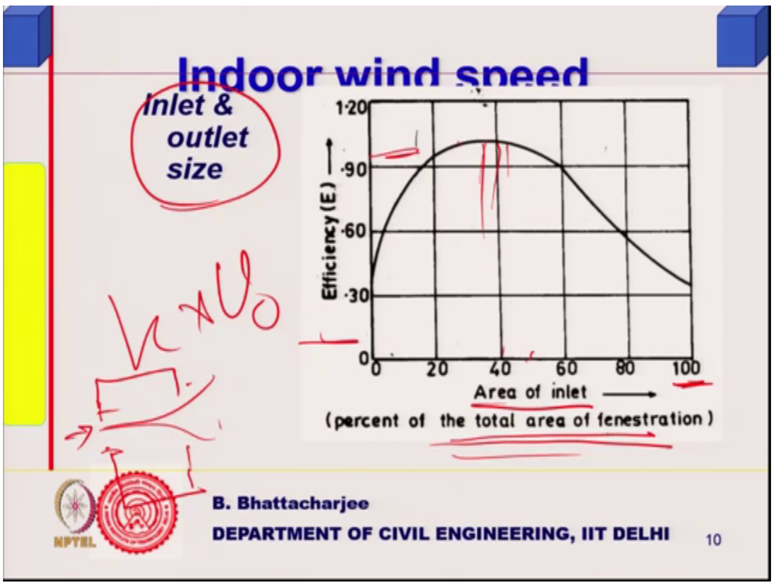
Let me just write it again. You know you will get v is in terms of some factor some k multiplied by v0. So, if you know the outside predominant velocity at the time you require, you can find out what will be the velocity, average velocity inside, at the level-desirable level that is your critical level and so on.

But its distribution is another thing. This is average distribution, is another thing. So, you might look into distribution also, but it also depends upon inlet and outlet size, ratio of inlet and outlet size and these are all empirical graph obtained from experimental studies and put in there, these all from SP 41, all from SP 41.

(Refer Slide Time: 14:27).



(Refer Slide Time: 14:52)



But this gives you at least the idea because we do not require that kind of accuracy in calculating the velocity which I will get it, because velocity outside will keep on changing. So, if I am trying to do a kind of fenestration design, which is for ventilation, which is permanent feature, all the time I am not going to get this velocity, but we can get the rough idea. For example, area of inlet to area and inlet to, you know as a percent of total area of fenestration.

So, 50 means inlet and outlet, I mean sorry 100 means inlet and outlet are same. Now, what is it area of inlet divided by percent of area total area of fenestration. So, only inlet, this is only inlet. 50 means inlet and outlet area is more or less.

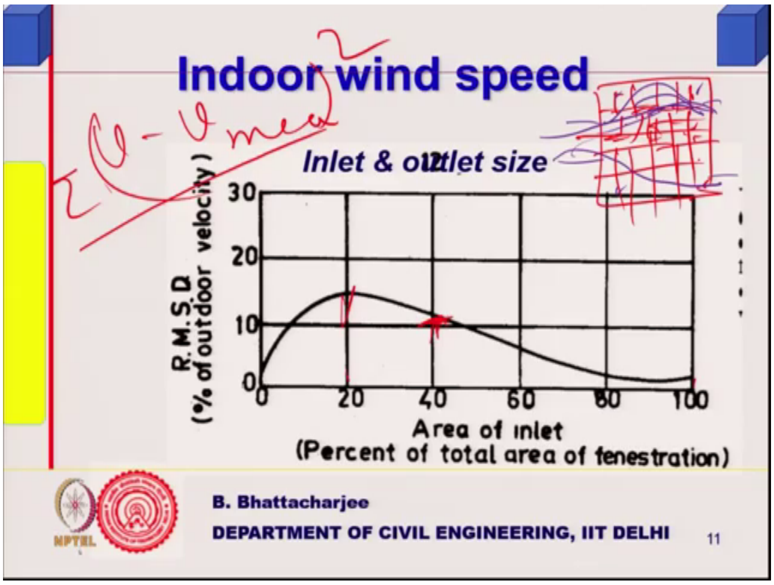
Student: Same.

Same so, if you see 40, slightly inlet is slightly higher, you get better coefficients efficiency is better. Better coefficient efficiency is more and what is efficiency? Efficiency is has to be multiplied actually.

So, efficiency is multiplied. This efficiency is 0.6. So, whatever you have got earlier, I said k multiplied by v0 that is what you got after select correction that should be multiplied by this efficiency. So, it becomes somewhat still less, depending upon inlet and outlet areas when they are equal, it is more efficient. This is still 0.9 or so, but it hardly goes to one. Still there is some reduction. So, that is what. That is what you know. So, efficiency you can actually approximately get.

So, its preferably inlet and outlet area should be nearly same or inlet should be actually about 40 percent of 35 - 40 percent of the outlet area. In other words, something like this, if this is my, you know smaller slightly smaller window area. So, this inlet area direction of wind is like this, should be slightly smaller than outlet area, then it gets distributed. Better average velocities somewhat better. So, this gives you some idea right? Some idea how you do it, right?

(Refer Slide Time: 17:17)



But then, roots mean square deviations, if you see because I talked of average. So far, so deviation. So, I can find out velocity at every point minus the velocity. Mean square it up, sum it up divided by the number of data point that I have taken, that becomes root mean square deviations. This varies maximum at 20 percent inlet. 20 percent inlet at 40 percent is about 10 percent deviation, 100 percent anywhere velocity itself is low, so deviation is also.

Student: (Refer Time: 17:53).

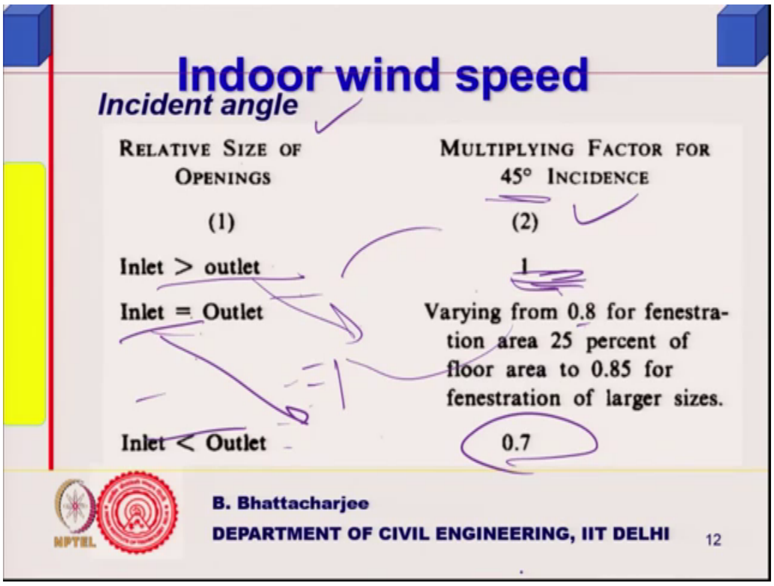
So, deviation is 40 percent, defined deviations is reasonably low value is relatively high. So, typically one might put it, you know if you can, if you have a prevailing wind direction known particularly in the condition when you want natural ventilation to occur, trend to keep the inlet area. Something around 40 percent, close to 40, but should not be too different and deviation standard.

Deviation variation also is less because distribution of the velocity in the whole room you know, if I have, this is my room, let us say, and I divide into several of rectangular portions and find out the velocity of the air, right rectangular grids and find out the velocities grid and find out the velocities, these velocities deviation of this one from the mean. Square it up, sum it up, divided by number of grids you have that will give you root mean square deviation.

So, these distributions all over the place are good. You know, it is around this, also is around 10 percent deviations root mean square divisions, 10 percent; that means, every corner you are getting some air movement. I mean you can understand this. Looking at it physically, you know for example, if I have inlet area somewhere there and outlet area somewhere there, air movement will be like this. Now, we will try to cover most of the areas. There will be some shadow corners, some shadow what 40 percent, but then, it has to or is also related to total fenestration areas you know. Area of the opening related to penetration areas.

So, if I have distribution will be more, but if it is small sized windows, they will just simply go straight. Window outlet is slightly more, it will tend to spread and distribute and then, go. That is why this variation you see, is somewhat less. So, that is keeping that, some sort of you know, an incident angle.

(Refer Slide Time: 19:51).

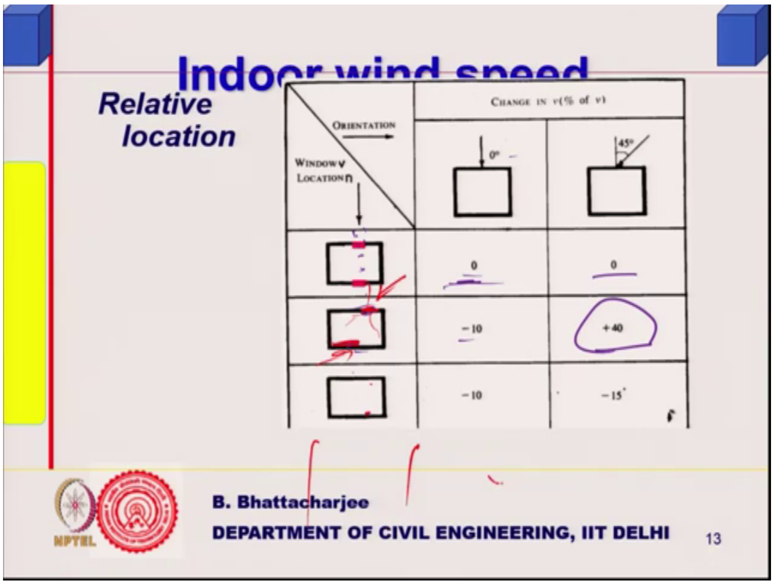


There are some corrections. Look at there are some 9 tables in SP 41 and you can go on adding those corrections one after another to approximately calculate the average, inside velocity that will get knowing the outside velocity.

So, there is another for incident angle correction, inlet greater than outlet. This value is one, right? If it is for 45 degree incidence, this is good for normal. We talked about for 45 degree angle. If inlet is greater than outlet, because it will drag in this manner, it will drag it, you know 45 degree inlet, it will drag inside and then, distribute. It will drag inside and distribute. So, 45 degree angle inlet equals to outlet 0.8 to 0.25 depending upon the floor area percentage of floor area. If it is 45 degree incident angle normal, we talked about. Now, we are talking of 45 degree incident angle.

And inlet smaller than outlet, because if it is inlet, it is large, Inlet is large and outlet is small 45 degree angle you know, this would actually distribution will be shadow areas, will be more actually. So, that is what it is saying, is around 0.7. So, this is a correction for your multiplying factor. So, like this if it is 45 degree angle of incidence.

(Refer Slide Time: 21:10).



Then, it says relative location of window, there is a huge table. I just picked up a portion of the table from SP 41. If I have window location facing each other, no correction these corrections are additive corrections.

So far all the corrections are multiplying, these are additive plus 10 percent minus 10 percent reduce the value by minus 10, increase the value by plus 40. So, window located, here, 0 degree in a normal incident, no correction 45 degree. No correction, same window location, same another window location here and there may be red color. Let me just use red. This may be window locations. No, it is not. Color uses something like this.

So, 45 degree plus 45 degree means, it might actually distribute the window in this manner and 0 degree, there will be reduction. So, you know window location. So, there are several such window locations given and again, these are based on local small internal studies from where they actually got those stable done long - long back right? So, change in v percentage of v, this much percentage of v would be change; that means, minus reduce it by 10 percent increase it by 40 percent, etc, etc. Relative location of the window in a single room, there are must been some window here, some window might have been, you know like some window.

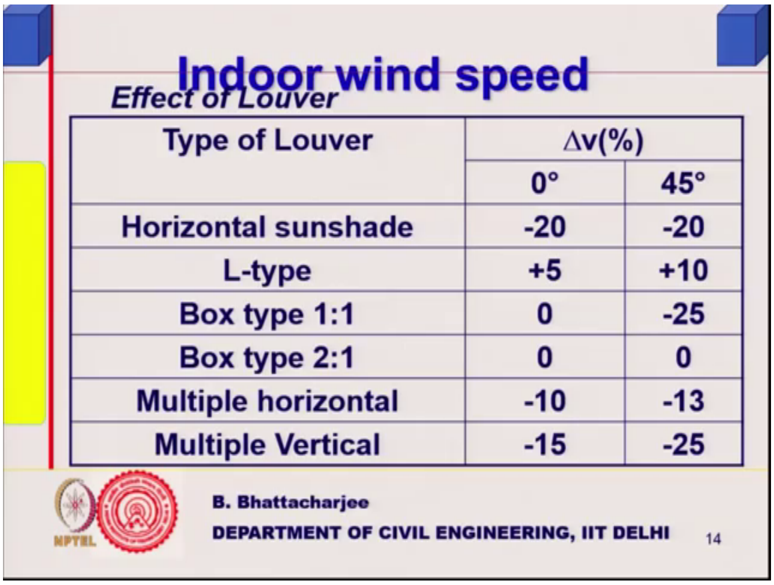
This was face to face; one is face to face, another is to end, you know and maybe other, I have only these two walls. They talking of about two walls, one at the center, one at the corner, something like that. There are series of combinations. I have taken only three of them. There are lot - lot more about, you know number of them actually, there are more I have not taken, that I just because you can always look into it and find it out, what I am trying to explain. What this means? Suppose you want to look into, how you look into it? So, that is all it is.

Student: (Refer Time: 23:11).

Student: data (Refer Time: 23:12).

Yeah. Experimentally determine, they determine experimentally in internal studies. Empirically, no equations calculated basis, no that would be calculation is difficult, because coefficients will always come and this far more complex. So today, modern day I do not go for CFD analysis straight way, but not for single room like this, you can simple - single room like this, you can use the same SP 41 concepts, effect of Louver.

(Refer Slide Time: 23:38).

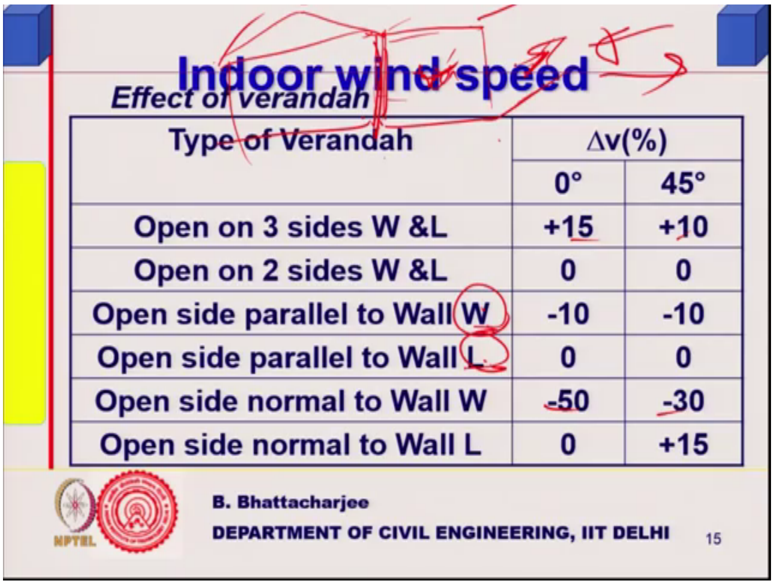


Type of Louver	Δv(%)	
	0°	45°
Horizontal sunshade	-20	-20
L-type	+5	+10
Box type 1:1	0	-25
Box type 2:1	0	0
Multiple horizontal	-10	-13
Multiple Vertical	-15	-25

That is again, there is another table and this is also additive delta v horizontal sunshade. They will reduce down because they, you know, they tend to direct the wind in a different direction, not at the critical level l type. They might increase; improve at 45 degree angle and 0 degree angle. Two cases, box type, no correction multiple horizontal something like this, multiple vertical something like this. So, these are correction in delta v, given for 0 degree and 45 degree angle of incidence for type of Louver sunshades. For example, this is horizontal sunshades.

So, I can have l type of Louver, l type of Louver or horizontal sunshade. A box type, you know we talked about this egg crate and all those. Some of those are those, how do they change? That is given - verandah will have something different something different, different effect of verandah they will.

(Refer Slide Time: 24:44).



Have something different, open on three sides. This is what you find in northeast or maybe Kerala, quite a bit you know, like you will have something like this. Roof will look like this something, like this right and you might have, this is how it is, right? So, this is a verand.

And if it is open on three sides - windward and leeward, then it might improve the situation. Open on two sides - windward and leeward, it will be something like this. Open side parallel to the wall that is, this. This is open parallel, this is the wall is open, this with this is open; these are closed, right? Open side parallel to the parallel to wall, open side parallel to wall in the windward direction and that is in the leeward direction.

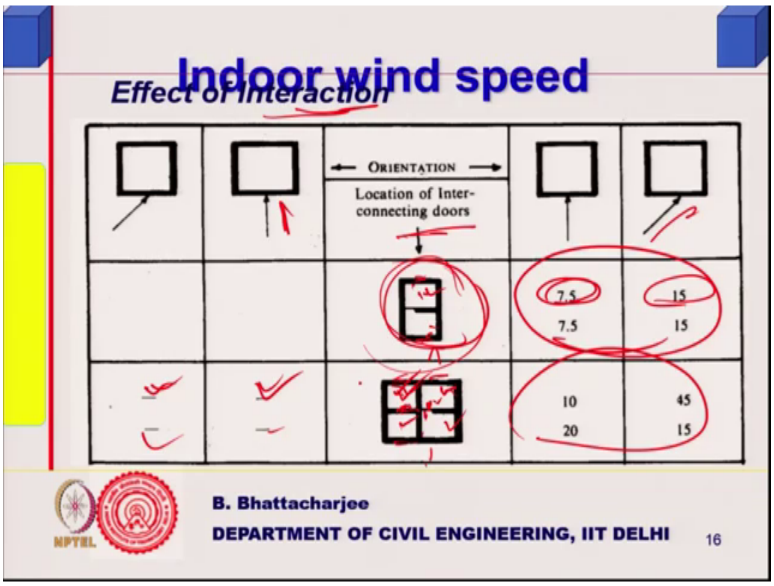
Supposing, wind direction is like this, this is the case and another case, wind direction is like this. This is the correction, open side normal to the wall, that is, these are the side suture normal to the wall, this is my wall, and this is my roof. You know this is my roof, this is my roof, and this is a wall. I have a verandah here, right? This is normal to the wall is, this side if it is open, then you get these corrections minus.

And if this is open, then you get better situation and if it is a windward or leeward, it will again depend up on that right. So, people provide verandah in those areas, maybe both sides, but usually not on both sides usually on the front side, where people enter into the house. You know, traditional housing if you see, where people enter into the house, they are they provide verand. Sometimes, they cover it up, front portion for privacy, but if you cover it up for, then they will have this kind of effect.

So, it is a step by step multiplicative correction. First one, we had for a fenestration area as a function of floor area inlet to outlet area. Numbers 2, number 3 was related to or see light. See light was first, was see light, then area of the fenestration, then was this one. These are all multiplicative after that though, when we started with the sunshades, they are all or location of the window started the location of the window. The position of the window, those are additive plus or minus, wherever it is written, plus and minus, they are actually plus and minus. All are percent of outside v0, because that would be known to you from climatic data.

So approximately, how much average velocity we are getting inside, you can actually calculated on what say 7, say 8 steps calculation, not very complex. Look into the table and just do these corrections. That is it. Ok, then effect of again another set of table. If you have 2 rooms connector, you know effect of connect indirect; you know effect of 2 rooms' connections, actually location of interconnection. So, effect of interconnection, interaction near this should be inter - connection.

(Refer Slide Time: 27:34).

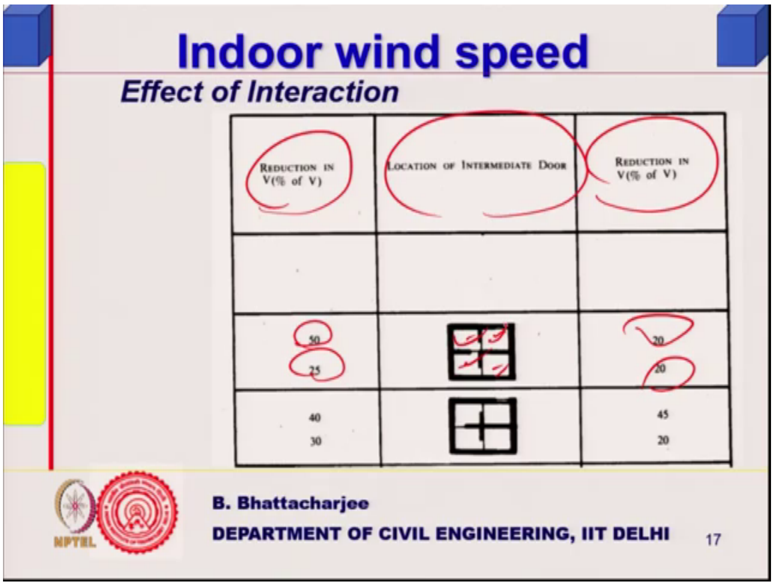


So, 2 rooms like this. Wind is from this direction and there may be window here, window there and wind is from 45 degree angle. So, this shows that in this room, you will have 7.5 percent added 15 percent added there and something like that and there will be some negative values also. Some cases it is not given. This for example, this is only 2 rooms. So, these 2 values are given. There are 4 rooms and there are no windows here. So therefore, no connectivity, there is no connectivity. There is connectivity only here therefore, this is given.

When you will have connectivity, here also there are windows on all places, you will have 4 values. This value corresponds to this room; this value corresponds to this room right? For normal window, direct wind direction like that and there has to be depending upon the connectivity, if there is only one connection here, there are no connections. That is why you get 4 values velocity.

So, this is for inter - connection between different rooms and similarly, there is another table I believe, yes there is more of it.

(Refer Slide Time: 29:05).



So, say this same continuing the same one. So 2 values given here, this correspond to this room, this correspond to this room, this correspond to this room and this corresponds to this room additive v reduction in v, this straight away given as reduction, this straight away given as reduction. So, one can, this is also reduction location of intermediate door - one intermediate window, intermediate door should be openings are usually there. So, that is how actually we, you know, we can calculate.

So, I think that it finishes our discussion on comfort ventilation as well.