Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 04

Appropriate Openings for reduced Operational Energy - Part 2

Hello students, we are back with another class of understanding the importance of openings where openings, how openings are crucial in assisting passive design and therefore, reducing the operational energy. In the last class, we saw the importance of openings, what are its benefits, what is the location of openings? How does that play an important role in ventilating a room? And use of wing walls, how does it influence indoor ventilation? In a very theoretical and brief conceptual manner we saw that. We will continue this class to understand how natural cooling can take place by virtue of positioning the openings. The position of openings with respect to the ground also creates a difference. Where do you locate the openings to enhance ventilation? Every time placing the opening at eye level may not be the most beneficial location. Proper positioning of openings helps us in regulating the temperature in indoor spaces, especially in warm and hot climates.

Placing inlets low in the room and outlets high in the room are effective measures. How are they effective? We will look at it a little later because we need to understand one concept here. Always cooler air sinks because cooler air is heavier and hot air rises. This principle must always be remembered.

Cooler air is heavier and it sinks or settles below. Warmer air is light and it always rises. So, this is the principle we need to understand and therefore, when you locate the opening in a inlet opening in a lower area, it helps push down cooler air through the space while locating the exhaust up and high and helps pull warmer air out of the space. So, what happens is; let us consider these three case scenarios. Here the opening is placed at a higher level.

At a higher level there is warm air. This air is warm. It becomes warm either because it is closer to the roof and therefore it becomes warm. It remains warm there. When you have an inlet like this, the breeze flows in and takes away the warm air. And takes away the warm air.

And in the meanwhile, due to the pressure differences, there is movement of breeze at a lower level. So, it is not a bad case scenario, but the impact of breeze movement is not felt directly under this condition. You can see many industries. They employ these techniques you can see that the industries have windows at a higher level -there are windows at a higher level in many industries if you have noted. So these- this acts like you have other window also. So, there is breeze movement across this and due to which there is some kind of an air movement not effective enough for you to feel or sense.

What happens when you have openings at a lower level? When you have openings, this is the inlet. When you have and here is the outlet. At a lower level, breeze flows in and goes out. There is cooler air at the lower level and warmer air at the upper level. Due to this movement, there is some kind of a breeze movement happening here due to pressure difference.

But if this is the working area then one can sense the breeze, but it depends on the scale of how large these openings are. If the openings are very small- if the openings are more like ventilators, then this breeze movement will happen and at a human scale level one will not be able to perceive the movement and this space will become extremely difficult thermally. Let us look at another case scenario. Where the openings are placed, inlet is placed at a higher level and outlet is placed at a lower level. What happens under this case is the breeze comes in, it is warmer and there is the outlet is here so it is compelled to settle down and go and it also pushes some amount of cool air along with it causing a little warmth in this area because it brings the warm air and it passes through the outlet and the cool breeze also in this process is pushed out.

So, it pushes the cooler air through the space. Locating the when you have the inlet air at a higher level. Now let us look at two different methods of achieving ventilation. One is called the stack effect and Stack effect uses temperature differences to move air. Hot air rises because it is lower in pressure and for this reason it is sometimes called buoyancy ventilation.

So, you have a stack here. Consider a scenario where there is a stack or a chimney. This chimney has openings to habitable spaces and there are openings on the other side of the chimney too. Here you have the attic ventilation and here you have the regular window opening. Breeze that comes in compelled to move through this chimney because the solar radiation falls on the chimney and makes the air in the chimney warm.

As we had discussed warm air tends to go up because it is lighter and cool air settles down and when the air in this chimney is warm the it has to be replaced it flows out causing a pressure difference due to the temperature difference and this air in the chimney gets replaced the air in the warm air in the chimney gets replaced by the fresh air which comes in and this is how Air movement or ventilation is, ventilation is instigated indoors due to the chimney. What happens? Air becomes warm. We may say the stack or the chimney becomes warm and the air becomes warm due to this. The air inside the chimney becomes warm because of which it becomes light and tends to flow out, tends to move out causing pressure differences and this creates this pressure difference because of this pressure difference the air is replaced by the air which comes through the inlet and therefore air moves inside the building and this causes ventilation or this encourages ventilation when you have a stack. Now this is the principle of a stack and you can see how stack effect can be used.

We will also understand what Bernoulli's principle is. It uses wind speed differences to move the air. It is a general principle of fluid dynamics. Saying that faster air moves, the lower its pressure. Architecturally speaking, outdoor air farther from the ground is less obstructed.

So it moves faster than lower air and thus has lower pressure. This lower pressure can help suck fresh air through the building. So, outdoor air which is farther from the ground should be less obstructed and hence it moves faster. It is a well known fact that breeze at an upper level is faster than breeze at the ground level. And hence it moves fast and therefore it has lower pressure.

This lower pressure helps suck fresh air through the building. We can see that example here. According to Bernoulli's principle, wind at upper level has more movement or it moves fast and what happens I would like to write this again in a more neat manner at a upper level wind moves fast and because of that it has lower pressure and because of which it will suck the air at lower level. So, air at lower level will be sucked up Because air at lower level neither has great momentum great velocity as compared to air at upper level and it is also does not have it is it has higher pressure. And this instigates air movement causing ventilation, provided you have facilitated an architectural element such as a tower or you have facilitated the movement of wind.

How? By having openings in appropriate location along with a stack. So architectural design becomes very important if you need to tap this concept and bring in ventilation. You can have this stack as part of your design or you can have dedicated stacks as shown here. You have stack 1, stack 2 and stack 3 all of which works on the same principle where know the wind moves fast at the upper layers causing low pressure and it sucks the air at a lower level which has less velocity and high pressure. We will look at another few examples of how architecturally this principle can be used. When you have tall rooms and probably clear story openings, these are openings at the top, clear story openings and there are inlets at lower level, then air movement is facilitated from lower level to higher level causing good indoor ventilation.

You have a tall room with other rooms at the edges then opening up both these rooms to facilitate ventilation can also cause breeze movement. In some buildings we can use staircase or atrium as an air stack. So, breeze enters and flows out through the stack which works on the same principle. So, what all can form stacks in any building? The stairwells, sometimes lift wells, atriums, courtyards can all form stack which works on Bernoulli's principle, provided - most important - provided you have given openings in an appropriate location and openings of appropriate sizes that will cause that will facilitate natural cooling with wind movement. Let us now look at solar chimney as a passive cooling design that uses the sun's heat to provide cooling using the stack effect.

So, stack effect can be used for two under two conditions. One is Bernoulli's principle which causes pressure differences and solar chimney which causes temperature differences. Solar heat gain warms a column of air which then rises and exits through opening at the top of the structure, pulling new outside air through the building. They are also called as thermal chimneys or thermosiphones. As though it's just the meaning of the word that by virtue of temperature difference, air is siphoned out because of the heat difference.

So, let us look at this first example. The first example has a solar chimney with vents on top. You can see these louvers. They are vents on top. Now the radiation of the sun causes the air in the chimney to warm up.

So air in the chimney warms up. And the air rises up because warm air rises up, cool air settles down. It rises up and escapes through the vents. This causes air movement and instigates ventilation. Provided you have openings below at appropriate locations of appropriate sizes.

Another case scenario where the solar chimney is designed in such a way that along the direction of the sun there is glass. And therefore, this makes the glass transmit solar radiation and the air becomes warm very quickly. And again the siphoning effect starts and cooler air flows up and air movement inside the building causes ventilation. There is another third case scenario where the solar chimney functions as a separate entity and is probably not part of the building as in the case of scenario A or B. You cannot see the solar chimney in C.

All you can see is a duct or a small hole. What happens again? You have glass here and the solar radiation penetrates through the glass and makes this air very warm due to which cool breeze gets sucked in and is siphoned out. In this process ventilation of indoor spaces is facilitated provided I would like to reiterate facilitated provided you have openings in appropriate location below the chimney and you have openings of appropriate sizes both are mandatory requirements. So, in today's class, we saw how opening plays a very crucial role in ventilation by virtue of their location and their size in facilitating indoor ventilation. We saw the use of stack either based on Bernoulli's principle or based on the solar chimney.

Which will instigate indoor ventilation based on the principle that warm air is light and it rises up, cool air is heavy and it settles down. Another thing we learned today is air at upper level is warmer and moves at a higher speed and it has less pressure while air at a lower level is heavy and is high in pressure and therefore the air at the top sucks the air at the bottom. It is up to us as architects how we use this principle. Architecturally, this principle can be used by designing a building to have clear story openings, openings at the top, having stairwells or having atriums. In this manner, we can encourage this air movement.

We will stop the class at this stage. Come back next class with another aspect of openings and that will be daylighting.