Climate and Built Environment
Lecture 8

Use of Fans

A ceiling fan does not cool a home, it cools people. It does so without changing indoor temperature, not even by one degree! How does cooling happen in that case? It is due to the movement of air. When we switch on the fan, we immediately begin to feel much better but it doesn't reduce the air temperature at all. What happens is, the wind begins to move around you and the sweat on your skin is taken away or is evaporated because of the wind movement because of which psychologically you feel much cooler compared to space without a fan or without air movement. This is how air cooling happens, the movement of air over the surface of your skin removes heat from a region physiologists call 'the boundary layer' - a warm layer of air that surrounds us at all times. When we are pushed beyond our skin temperature, we begin to sweat. When we cross 35 or 36 degree celsius, we begin to sweat. There is also a constant hot air present around our skin and that is also due to the process like respiration, convection and radiation that we discussed in our earlier presentation about human heat balance. Due to all these processes, we are always surrounded by hot air because of which we begin to sweat. To get rid of the sweat, we need air to constantly move around us, this is created by using ceiling fans/ table fans or any other electrical fan systems. By stripping heat from the boundary layer, a ceiling fan makes us feel as if the air in the room is about 4 Fahrenheit degrees cooler. Although air temperature cannot be reduced, it is made possible with the help of the ceiling fan, psychologically you begin to feel 4 degrees cooler. In a climate such as a warm and humid climate where the humidity is very high, the human body begins to sweat constantly. In order to remove this heat, we need air or the presence of a ceiling or table fan becomes very essential. Ceiling fans are especially effective cooling fans back in the early or late cooling season when all you needed was slight temperature decrease. This is again about the reduction or psychological effect of temperature not in the actual air temperature. Fans provide reliable air movement for cooling people and supplementing breezes during still periods. When there is no movement of air, you would use fans that begin to rotate and move the air that is still, in turn creating wind. That is why we feel the air is constantly moving in presence of a ceiling fan and when the ceiling fan isn't present, you feel the air to be completely still. At 50% relative humidity, air movement of 0.5m/s creates maximum cooling effect. Within a building if the relative humidity is 50%, even with the presence of 0.5m/s of wind speed you feel much cooler. Faster speeds can be unsettling. As noted above, air speeds up to 1.0m/s can be useful in higher relative humidity, but prolonged air speeds above 1.0m/s causes discomfort. This 0.5m/s to 1.0 m/s can be used for spaces where the relative humidity is very high. For spaces such as; close to the coastal region, hot and humid climatic condition, these type of winds can be beneficial. As the windspeed increases to 1 m/s, your hair starts moving constantly and the lighter objects placed in the room starts moving, creates discomfort and distractions. This is the relation between the height above the floor level to the wind speed. As you see here, as the height scales up, the wind speed reduces due to the configuration of the ceiling fan.

Standard ceiling fans can create a comfortable environment when temperature and relative humidity levels are within acceptable ranges. The fan is going to make the air circulate. It is not going to reduce the air temperature or the relative humidity. A fan is beneficial only in places where you can handle the humidity levels and the air temperature. If your humidity levels become high, say 90% of relative humidity is what is within your room, even though air is present you won't feel comfortable since the relative humidity is very high and cannot be taken care of by ceiling fans or table fans. In such cases, you might need to switch de-humidifiers in which mechanically the humidity levels will be controlled. In a lightweight building in a warm temperate climate, the insulation of fans in bedrooms and all living areas including kitchens and undercover outdoor areas significantly reduce cooling energy use.

As we know lightweight buildings refer to buildings that make use of lightweight materials that are capable of releasing heat as quick as possible. In such type of construction methodologies, using ceiling fans can be much more effective when compared to heavy weight construction methodology. Due to the presence of lightweight material, the hot air is going to escape quickly and the cool air is going to get circulated with the help of a fan.

Whole of house fans are ideal for cooling buildings particularly where cross ventilation design are inadequate. However, they do not create sufficient airspeed to cool occupants. If your building does not encourage you to have proper cross ventilation in your design, say if you are very close to tall structures, then the presence of prevailing or the air movement that is going to happen around the building or taking advantage of the air movement inside your interior spaces can be much more difficult or challenging. Inside your interior spaces, it can be much more difficult or challenging. In those spaces, a ceiling fan can be beneficial compared to having windows or still air. Whole of house fans should be positioned centrally, eg: in the roof, stairwell or hallway. We must have noticed in our plans and diagrams when we are locating our fan for the living room you would position your furniture’s and just above the furniture, you would locate the centre by drawing a cross mark above your furniture layout and then you create a centre point above your usable space and locate the fan just above the usable space because there is no point in keeping a ceiling fan on the corridor or the spaces that are less frequented.

You need to locate your ceiling fans or any type of table fan or a fan that is going to get installed on your walls, you need to locate it in such a way it caters to the usable spaces. Typically, a single fan unit is installed in a circulation space in the centre of the house, hallway or a stairwell to draw cooler outside air into the building through open windows in selected rooms when conditions are suitable. If you are having a space in which a cooler air is present and you cannot actually take it in completely, you can use a fan which can drive the cooler air at a lower level and that can be sucked in and distributed to various spaces within your building. It then exhausts the warm air through eaves, ceiling or gable vents via the roof space. This also cools the roof space and reduces any temperature differential cross ceiling insulation. As we discussed in our previous presentation, the hot air rises above and the cool air settles down. The used up hot air rises above and if you are keeping a small space for ventilation on your roof or your eaves, that opening can be used to suck out the hot air. Control systems should prevent the fan operating when external air temperatures are higher than internal.

Drawing large volumes of humid air through the roof spaces can increase condensation. A dew-point is formed when this humid air comes in contact with roof elements i.e Reflective insulation that has been cooled by radiation to night skies. If you are going to keep a nocturnal cooling effect on your ceiling, then the cool air present just above the roof can be sucked in by the presence of your mechanical fans and it can be circulated to other parts of your room. Depending on the type of design you are going to choose for your cooling, it can be made into a combination of that. Whole of house fans can be noisy at full speed but are generally operated in the early evening when cooling needs to increase since households are generally most active during those hours. If it runs at a lower speed throughout the night, they can draw cool air by night across beds that are near open windows,provided the doors are left open for circulation. On still nights this can be more effective than air conditioning for night-time sleeping comfort.

If you are located in a place where air is going to be still most of the time, using fans can be much more beneficial rather than keeping air conditioning because when the fan is made to run at a lower temperature, it can draw the cool outdoor breeze from outside and make the breeze circulate around your bed in turn making you feel like it were 4 - 5 degrees less. Whereas if you opt for an air conditioner instead, it is just going to add to your energy bill and it might not be as effective as using a ceiling fan for this type of climate.

Roof-space: Well-ventilated roof spaces and other non-habitable spaces play a critical role in passive cooling by providing a buffer zone between internal and external spaces in the most difficult areas to shade the roof. For a climate where passive cooling is required, the roof is the space that is going to get heated up quicker. So you need to design a roof space in such a way that it will be able to release the used up hot air. The hot air that has risen due to the lower openings and the pressure difference that has been created. Roof space becomes a crucial factor if you are designing for a warm-humid or a hot and dry climatic condition. As you see in this picture, openings have been created at lower level and there is vegetation as well. Due to vegetation, the presence of deciduous trees that are going to have leaves throughout the year, the sun rays that fall are going to get blocked due to the presence of vegetation, it will get more cooler and this shaded air is going to get inside houses. Cross ventilation happens and due to the presence of a small opening that is above the usable space the hot air is going to escape, this promotes cross ventilation. You must note that there is a temperature difference of 8 - 20 degree celsius compared to the outdoor and indoor spaces. Here, insulation is present to block the hot air from outside from getting in inside. There is an insulation that is happening on the roof, the temperature will start getting higher and higher since there is no opening. Hence, it is very ideal to create a smaller vent on the top of the roof to make this hot air escape outside. As we can see here, there is a small opening here, that makes the 65 degree celsius to escape, making it equivalent to the air temperature outside i.e 45 degree Celsius.

Well-ventilated roof spaces form a buffer between internal and external areas. Ventilators can reduce the temperature differential across ceiling insulation, increasing its effectiveness by as much as 100%. Although your ceiling might have an insulation layer, if your hot air is going to get accumulated above your insulation, it is going to reduce the cooling effect or even mechanical ventilation such as air conditioning. The effect of cooling is going to get much lesser due to the presence of hot air. You can keep small vents for the hot air to escape thereby making the insulation 100% effective. The use of foil insulation and light coloured roofing limits radiat heat flow into the roof space. Use careful detailing to prevent condensation from saturating the ceiling and insulation. Dew-points from where humid air comes into contact with a cooler surface i.e the underside of roof sarking or reflective foil insulation cooled by radiation to a clear night sky. Depending on the cooling effect you use at night, the insulation patterns can be altered as well.

As you can see here, the eaves have been ventilated here. The air begins to flow and due to the presence of the eave vent, the hot air goes in and there is a vent that is going to move depending upon the pressure difference between the exterior and interior spaces. The vent is going to take away the hot air that has been accumulated on the cable roof on the projected roof and is going to let it escape in the atmosphere. This is for an air conditioned room. However, if you do not have an air conditioned room, the insulator isn't present which makes the temperature difference between the room and the roof, very less. Having more number of vents available for hot air to escape becomes very essential when compared to an air conditioned space.

Venturi Effect

Moving on to the Venturi effect, the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase to allow the same volume of air to pass through the constricted opening. The Bernoulli Principle explains the inverse relationship between speed and pressure, meaning that this creates a drop in pressure due to the increase in speed. As you can here in the image below, the pipe has higher diameter on one end and there is a sudden drop in diameter in the middle and then again, the diameter of the pipe has been increased. What happens is, when the air starts to move from this direction i.e A1 and due to the sudden reduction in the width of the pipe, the air speed begins to increase since there is a negative pressure that has been created on the other end of the pipe. Since the opening has suddenly reduced, the airspeed starts to reduce and in a narrower section, the air speed begins to increase tremendously when compared to the inlet point. When you need to enhance your airspeed, say if you are located in a place where the air speed is very less, for those points Venturi effect will be much more effective to achieve passive cooling or psychological cooling effect because the airspeed will increase tremendously due to the effect of making the air pass through a smaller section or smaller opening. This phenomenon can be used to draw air out of a building usually at the roofline using the movement of the outside air. This can be made reverse also if you want to move the hot air that has been used up in the building to the outside. That can also be done by the presence of the Venturi effect. One example is the Venturi effect on Hannover Pavilion. The hot air that has been used up, rises and there is a small opening that has been provided on the roof which makes the air to move above and due to the small opening, the speed increases as the air current gushes through the small opening and the heat goes outside.

As you'd notice here, the Hannover Pavilion. You can see how small openings have been created on the roof for the hot air which is rising above to escape. This is much more beneficial during summer when the air temperature is very high.

Moving onto the Stack effect, the molecules of warm air are moving at a faster rate, are more agitated and therefore, create more space between these molecules. This means that hot air less dense than cold air, making the lighter air to rise relative to the cooler air. As we saw earlier, as the hot air rises above space has been created due to the less agitation amongst the molecules because of which there is an empty space which has been created and the dense cool air starts to move into this empty space and starts to occupy the empty space. The rising of hot air and the filling of the space with cool air is called the Stack effect.

This generates a vertical pressure difference dependent upon the average temperature difference between the column of warm air and the external temperature and the height of the column of warm air. This causes the warm air to tend to flow out of the opening at the top of the building and draw in air near the ground. What happens in stack effect is pressure difference. This happens in a vertical direction. In buildings, the vertical dimension is called as stack effect and there is a pressure difference that has been created on the top of the building to the lower pressure of the building. This makes the hot air to rise. Having ventilation here helps the hot air to escape. Whereas, keeping lower vents will draw in the cool air. Compared to keeping a huge opening on the top very close to the outlet, keeping an opening just below the wind tower or a vertical tower of the building can be much more beneficial cause it creates a huge difference in the pressure zone and the space between the high pressure zone and the lower pressure zone is much higher which will make the air move at a higher speed. This is a stack-induced effect in which the opening is created on the lower side , through which the cooler air is going to get drawn in and the used up air is going to move above and there are openings above your tower through which the hot air will escape. This is a case example for Stack effect. This is present in Okanagan College Centre of Excellence in Sustainable Building Technologies and Renewable Energy Conservation, 2010, located in Canada. This building has taller openings and the lower portion through which the cool air comes in and the incoming fresh air is circulated throughout the building and the used up air starts to move in these vents present above the room. Then, it starts to move upward due to the presence of a tall tower that creates a path for hot and used up air to move up above. This air starts move above and due to the presence openings on top of the tower here, the used up air goes out.

Cooler air, being denser will enter from openings lower down the building and the success of this system is dependent upon the volume of air it moves through the building. The higher the stack, the greater the flow, a fact which can be seen in traditional and vernacular buildings when this method has long been used. Mechanical ventilation ensures constant airflow through the building and this is done by forcing air through ducting with or without the help of fans, thus using a lot of energy with consequent CO_2 emissions. Keeping your apertures at a sensible location will reduce the use of energy, not only reduces the energy of your air conditioning spaces but it also reduces the usage of winds or fans to drive the cool air from outside. Keeping an opening at a lower level along your prevailing wind direction or a zone in which cooler air is present. Keeping an opening at the taller portion that will make the wind flow through your building throughout, which will help reduce the use of your ceiling fans. This will elevate human comfort without reflecting on your energy bills.

This is how the building looks. There are smaller openings on the lower levels which are protected by vegetation as we can see here. There is a wind tower that has been much more taller compared to the rest of the building because the higher the tower, the better the stack effect. If the tower is taller, the wind speed will get affected causing the wind to move throughout your building causing the hot air to escape outside.

Courtyard Effect

Moving on to the Courtyard effect, due to solar radiation in a courtyard, the air gets warmer and rises. Cool air from the ground level flows through the louvered openings of rooms surrounding a courtyard, thus producing air flow. At night, the warm roof surfaces get cooled by convection and radiation. So, when there is a courtyard present in your house, a proportional opening in between your house, the solar radiation that is going to fall on your courtyard will start to heat up the air and the warm air will rise above. Due to the warm air rising above, the emptiness present in the courtyard will start to draw air from the surrounding rooms that are going to have cooler air. The cooler air from the surroundings will then begin to move to the courtyard's empty zone. The cool air will then move to your rooms which are going to be beneficial for the occupants. At night, the warmer roof gets cooled by convection and radiation. During the night the reverse happens, the courtyard begins to lose all the heat that has been stored up, it will start to release all the heat and by convection and radiation, the temperature will become lesser at night. During the night, the courtyard will be made into a living space compared to your bedrooms, the courtyards will be much more beneficial. If this heat exchange reduces roof surface temperature to wet bulb temperature of hot condensation of atmospheric moisture. This occurs on the roof and the gain due to condensation limits further cooling. As you can see here, the architecture can be modified depending on the sun angle in which your room or interior space can be blocked by projected eaves or projected planter boxes which can reduce the instant solar radiation. This is a typical example of a courtyard. If the roof surfaces are sloped towards the internal courtyard, the cool air sinks into the court and enters the living space through low-level openings, get warmed up and leaves the room through higher-level openings. There are openings on the lower level, it draws the cooler air inside and the cooler air gets circulated within the building. Due to the presence of openings in the higher ends of the rooms, the used up hot air starts to rise above causing the hot air on top to escape outside.

This is an example of vernacular architecture for Karaikkudi. This is urban planning which has been planned in a grid pattern. This represents the weather status of a whole year in Karaikudi. It is almost the same throughout the year, there are hardly any seasonal differences. Summer falls between April to end of July and monsoon between October to December. This is how the streets have been planned. As you can see, the sun moves from east to west towards the south. There are two courtyards present. Case study has been conducted for an occupant living in this space. This is how the house looks on a cross section and the temperature has been noted for two days in which we have observed that the outside temperature varies from 28 degree Celsius and it goes above 34 degree Celsius. There are different spaces with different temperatures. The roof has been projected almost 2m and the temperature falls within the comfort range but the humidity begins to increase. However, when the roof has been projected much lesser, the air temperature begins to increase but the relative humidity starts to fall within comfort. It is also conducted for a space without openings, the temperature has been maintained constantly. The blue line without any openings. Even though this temperature can be beneficial, due to the lack of air movement, the relative humidity starts to build up. When you are designing for this climate, you need to take care of both air temperature as well as relative humidity present in there.