Energy Efficient Architecture

Lecture 8

Ventilation

Ventilation - the act of supplying fresh air to get rid of foul air. When you are supplying fresh air to remove the air already present in the space, it is called as ventilation.

Natural ventilation and air movement could be considered under the heading of 'structural controls' as it does not rely on form of energy supply or mechanical installation but due to its importance for human comfort, it deserves a separate section. The presence of openings - windows, doors, skylights; whatever opening you have in your structure to draw ventilation or air into your interior spaces is called structural control because you are not going to use any extra or artificial systems to take the air from outside. This is called structural or natural ventilation systems.

Why do we need ventilation systems in our buildings? To keep fresh air for our respiratory system, to preserve oxygen level in the air and control carbon dioxide. As the occupants are constantly using the air within the space, we are breathing in oxygen and letting out carbon dioxide. To maintain a good amount of oxygen present in the air we are surrounded in, we need ventilation to constantly remove the used up carbon dioxide and to supply fresh oxygen. To control moisture levels, if you are in a closed space, the humidity level keeps increasing and we might end up sweating and after a certain level, we cannot even have evaporative losses from our body since it is going to cause adverse thermal comfort effects. Lowering heat level and remove dust and odors. To satisfy all these important strategies, we need good ventilation systems which has been decided by our openings and system of ventilation that we will be choosing in our design.

System of ventilation - ventilation can be classified into two major systems; Natural Ventilation and Mechanical ventilation. Natural ventilation is like structural control - the openings you have in your building and you don't need any external or mechanical energy source to drive in the

air. But mechanical system uses artificial appliances to drive in the air from outside and to take it and use it in interior spaces to satisfy or keep us in thermal comfort.

Natural Ventilation

Let us have a look at Natural Ventilation - Natural ventilation is the use of wind and temperature differences to create airflows in and through buildings. So when you are having ventilation, it drives the wind. Due to the presence of temperature differences or pressure differences into your building, this is called natural ventilation. The effects of natural ventilation are; Buoyancy and Wind effect. Buoyancy effect is by creating openings in your roofs and creating a pressure difference and making the wind escape from one side which makes the wind to draw to this point and get used up. This is called Buoyancy effect and the wind effect is normally through openings which come in through our windows and doors. There is another window that happens to take advantage of the cross ventilation and it lets out the used air outside.

Natural ventilation - Buoyancy ventilation is more commonly referred to as temperature - induced or stack ventilation. Wind ventilation supplies air from a positive pressure through openings on the windward side of the building and exhausts air to a negative pressure on the leeward side. Windward side is the direction in which the wind is going to flow and the leeward side is where there is no wind but pressure difference because of which your used up air will automatically go to that place. This is called the leeward side of the building. Airflow rate depends on the wind speed and direction as well as the size of openings. Before you start designing, you need to be aware of how much wind does your locality have and which direction is the prevailing wind we have flowing towards. Also, how much wind we need to make the occupant comfortable within the interior spaces or for which activity are we going to design. For instance, if we are going to design for activity like a space for martial arts. The person who is going to practice martial arts is going to sweat constantly, they need more amount of air passing through the place. If it is for a classroom, more ventilation can be avoided or lessened to keep them within thermal comfort, just to keep them within thermal comfort and excessive

ventilation can be avoided since it might lead to flying of papers, disturbing students and distracting them as well.

To understand this better, we need to understand Ventilation requirements. Requirements for an acceptable amount of fresh air supply in buildings will vary depending on the nature of occupation and activity. As I just said, depending on activity pattern and how much heat loss a person is going to have in a space, depending on the activity they are going to perform within the space, this ventilation requirement usually differs. This is calculated by the quantity of air by the room volume and multiplying by the occupancy.

It is Air changes per hour = quantity of air x occupancy BY room volume. Quantity of air that can be be held in a room into how many people are going to use the room divided by room volume is what is going to give how much air exchange we need per hour. To sum up - what is ventilation? The process of supplying and removing air through an indoor space without using mechanical systems. It refers to the flow of external air to an indoor space as a result of pressure or temperature differences. By creating pressure difference when we draw air from outside to inside, this is called natural ventilation system. This doesn't use any other external power source. Hence, it is called natural ventilation.

What are the benefits of Natural ventilation? Improved indoor air quality, it constantly removes the used up air. Energy saving, it does not depend on any other external energy source which is going to help save your energy bills. Reduction of greenhouse gas emissions, we are not going to add CFC's or carbon dioxide which causes ozone depletion, this is an environmental benefit of this method. It gives the occupant control. It is not like a set temperature that works between a particular temperature range. If they want they can open a window, if they feel its colder, they can control it. It gives each individual the occupant control, who are going to use the space. Reduction in occupant illness associated with sick building syndrome . The building which doesn't have proper daylighting or ventilation is called sick building syndrome, it will cause the occupants feeling sick to use the space, is precisely what it means. We need good

ventilation and daylight, to satisfy our basic economic need, which will also increase our productivity by making us feel fresh and motivated to work more.

Design Recommendations - what are the design articulations that we need to do, to achieve natural ventilation. Building orientation and locations, Building forms and dimensions, window typologies and operations, Types, shape and size of openings, Construction methods and detailing. These are some of the principles we need to follow by preparing the schematic design stage. We need to choose which space what activity pattern is going to take place. How many air changes are now needed in each room? How much is the window size required to be assigned for each room? All this is done to maintain our thermal comfort. Urban planning consideration, we need to create a building that does not affect the buildings around or obstruct the windflow pattern because of your building.

Types of natural ventilation - Wind effect, Stack effect and Combustion and ventilation effect.

Stack effect and Bernoulli's principle - Two kinds of passive ventilation that use air pressure differences due to height to pull air through the building. Lower pressures higher in the building, help pull air upward. This is very similar to the wind tower principle that we saw in the previous chapter. We are creating pressure difference to pull air through the building since creating a tall tower or tall building, there is a pressure difference happening. A positive pressure and negative pressure is happening which causes the heated air to escape out the window, this creates a void at a certain point and this makes the opening draw wind from one side. This is called Stack effect.

The difference between stack ventilation and Bernoulli's principle is where the pressure difference comes from. Here, the wind comes from this side which is positive pressure and this is the negative pressure through which the wind is going to escape. Lower air pressures at higher heights can passively pull air through a building. If you are making your opening here and you are going to take wind from outside through the lower opening, positive pressure is

created here and the occupant is going to use the air. The used up air scales upward. Since there is a negative pressure that is now created since there is no opening there, no fresh air that is present, which makes that void space a negative pressure point. Due to negative pressure, there is constant pressure difference. Due to which the used up air automatically rises above and that is being taken out due to the opening present on the top.

Stack Ventilation - temperature difference to move air. Hot air rises because it is lower pressure. When we use air, we usually take up all the relative humidity. The air becomes more hot and dry which makes the air much more lighter. As we already know, the lighter objects go up, the air that is being used becomes dry, it is light and it moves up and the used up air is taken out. This effect is called Stack effect. For this reason, it is sometimes called buoyancy ventilation. As you can see the Stack effect - hot air rises due to buoyancy and its low pressure sucks in fresh air from outside. Here, there is an opening from which an inlet is going to happen and there is a top opening through which hot air escapes. Due to the hot air and low pressure difference, this effect of buoyancy is also called as Buoyancy ventilation.

Bernoulli's principle uses wind speed differences to move air. It is a general principle of fluid dynamics, saying that the faster air moves, the lower its pressure. If the pressure is going to be lower, the air is going to move much faster. Wherever you need good ventilation, it is important to create a much negative or lesser pressure, air automatically moves or draws to that place creating a draft or a constant windflow. The advantage of Bernoulli's principle over the stack effect is that it multiples the effectiveness of wind ventilation. Since you have the advantage of creating such negative pressure at a point, it constantly dries the wind and you can feel much more colder in this type of system. If people are in a room where they constantly sweat, it is best to go with this principle because it will constantly draw the air within the space. The advantage of stack ventilation over Bernoulli's principle is that it does not need wind, it works just well on still, breezeless days when it may be most needed.

The advantage of the Stack effect of Bernoulli is, Bernoulli has to have wind for it to flow from high pressure to lower pressure. Whereas in stack effect, if it is a still wind or no wind at all, you can still benefited out of stack ventilation system. Depending on your locality and windrose pattern and availability of wind (how much wind you have per meter square), you can choose your design system of ventilation according to your climatic zones. In many cases, designing for one effectively design for both, but some strategies can be employed to emphasize one or the other. For instance, a simple chimney optimizes for the stack effect, while wind scoops optimizes for Bernoulli's principle. It can even be used as a combination for seasonal variations or it can be used like having one solar chimney that can contribute to stack effect or having a wind scoop can contribute to Bernoulli's principle.

This is one case study that is present in London, it is called BedZED. The specially designed wind cowls in the BedZED development use the faster winds above rooftops for passive ventilation. In UK usually, the ventilation rates are very high and we usually feel the air is constantly being flown in almost 4m per second or more. Windscoop is very effective in areas that have good wind because it can draw the wind from one point and it can ventilate throughout the space and the used up air can escape from other openings. They have both intake and outlet so that the fast rooftop winds get scooped into buildings and larger outlets create lower pressures to naturally suck air out. This is by creating two different set of openings, one to take in the air from the roof and one set of openings to let out the air that has been used up. This is one point in which air is being exhausted, there is an opening therein which air is being drawn. This is being oriented according to the wind direction of UK.

Wind ventilation - This is the easiest, most common and often least expensive form of passive cooling and ventilation. Successful wind ventilation is determined by having high thermal comfort and adequate fresh air for ventilated spaces. This is very simple, how we have windows, doors and openings. This process where wind goes in and comes out is called wind ventilation. This is much more easier and a simpler technique to achieve. This is a much more easier and simpler technique to achieve thermal comfort and natural ventilation.

Using the wind for passive cooling and fresh air. If you see, there are two openings, one opening through which wind is going to come in and parallel to this window, you have another window through which used air is going to pass through, to the exterior. This is due to the wind direction present in that area i.e wind, coming from one direction and the used up air is being sucked out from the other opening.

Strategies for wind ventilation - The keys to good wind ventilation design are the building orientation and massing, as well as sizing and placing openings appropriately for the climate. In order to maximize wind ventilation, you'll want the pressure difference between the windward (inlet) and leeward (outlet) to be maximized. To increase the effective wind ventilation, we need to find out the windward direction which means the direction in which the prevailing winds are. Over the years, which months you are going to have wind blowing from which direction. You need to understand which direction and create openings in those directions to take advantage of the wind that is going to flow in and the leeward direction in which there is absolutely no wind and due to leeward side that has negative pressure and the windward side has positive pressure. The wind that is coming in from the windside direction is automatically going to move out through the leeward side direction.

Mechanical Ventilation

Mechanical ventilation systems circulate fresh air using ducts and fans rather than relying on airflow through windows. This type of system uses different types of ducts and fans to circulate the air that has been cooled or chilled to different parts of the building and it doesn't rely on windows. This is more effective for multi-storeyed buildings or spaces in which there is absolutely no air and you need to constantly maintain the spaces within temperature limits and to have a controlled ventilation system, this is much more better when compared to natural ventilation. These are some of the fans that take up the wind that is present around the building and these are some of the examples of ducts which are used to circulate the centre air to the front part. If there is a tall building and your building is surrounded by a lot of other taller

buildings, there is no way that wind is going to come inside through all your windows. To integrate, your mechanical ventilation will be much effective to distribute air throughout all your spaces.

Benefits of Mechanical Ventilation - Better indoor air quality - can remove pollutants, allergens and moisture that can cause mold problems. More control - provides proper fresh air flow along with appropriate locations for intake and exhaust. When you want to have a much more controlled effect, you need to control the amount of moisture in your air or if you want to remove allergens, or foul smell. Say you are surrounded by air that smells bad, you can't let that air come into your house, you'd rather have that foul smell removed and clean air to come in, to incorporate such strategies, it's better to choose mechanical ventilation systems. Improved comfort - allows a constant flow of outside air into the home and can also provide filtration, de-humidification and conditioning of the incoming air from outside. It can control your infiltration to stop your exterior air from coming inside. You can have restricted flow of air. You can also use de-humidifiers to maintain your relative humidity levels present in the air.

System of Mechanical Ventilation - these systems employ an electrically driven fan or fans to provide the necessary air movement. They also ensure a specified air change and the air under fan pressure can be forced through filters. There are three types of mechanical ventilation systems; Natural inlet and mechanical extract (exhaust system). These are different combinations of mechanical ventilation systems. The first one - natural inlet and mechanical outlet uses natural way in which the wind can come in but the wind to be taken out of the building is through a mechanical system because you don't need air to constantly be circulated inside if there is no proper outlet to go in. In such scenarios, you need to create a suction effect in which the used up can be taken out of the building. The Mechanical inlet and natural extract, if there is no wind present outside, you need suction to take air from outside and bring air inside your building. For this system you can use mechanical inlet and natural outlet. There is a third system that makes use of mechanical inlet as well as mechanical extract. There is

absolutely no wind to come in or escape. In both cases, incoming and outgoing, you can use mechanical systems.

Natural inlet and Mechanical Extract - This is the most common type of system and is used for kitchens, workshops, laboratories, internal sanitary apartments, garages and assembly halls. The fan creates negative pressure on its inlet side and this causes the air inside the room to move towards the fan and the room air is displaced by the fresh air from outside the room. Here the fan is being used which creates a negative pressure on its insides, inlet side, this causes the air to move towards the fan and the room is being displaced by fresh air inside the room. As the fan is being used, the air gets circulated. This is an ideal example for Natural inlet and Mechanical extract.

Mechanical Inlet and Natural Extract - It is essential with this system that the air is heated before it is forced into the building. This heats the air before it comes in. The air can flow from higher temperature to lower temperature, according to this fundamental, this system works. This system may be used for boiler rooms, offices and certain types of factories. The air may be heated in a central plant and ducted to the various rooms or unit fan convectors may be used. This heating of air can happen at one point and it can have a natural extract on the other side. Due to the difference in temperature, the air automatically circulates towards the natural extract.

Mechanical Inlet and Mechanical Outlet - this provides the best possible system of ventilation but it is also the most expensive and is used for many types of buildings including cinemas, theatres, offices, lecture halls, dance halls, restaurants, departmental stores and sports centers. The system is essential for opening theatres and sterilizing rooms. As you might have observed, all these building typologies needs a controlled system of ventilation or controlled temperature levels to keep us within thermal comfort levels due to its high occupancy or the activity pattern that is being following inside the house. To have a controlled effect, we are going to opt for Mechanical inlet and outlet even though it is much more expensive when compared to any

other system that we discussed. The system is essential for opening theatres and sterilizing rooms. This is much more effective and you need places like hospitals, sterilizing rooms where the air quality is very ideal and you cannot risk the quality of air. In such cases, you need to opt for Mechanical inlet and outlet.

Ventilation and building design - Massing Strategies for Passive cooling. Thinner buildings increase the ratio of surface area to volume. This will make utilizing natural ventilation for passive cooling easy. Conversely, a deep floor plan will make a natural ventilation difficult especially getting air into the core of the building and may require mechanical ventilation. If you are making your building thinner, the breadth to length ratio, then it is much more effective for natural ventilation to reach all the sides of your building and the same applies for your daylighting as well. The thinner the building, the more effective daylighting and natural ventilation you are going to get. Tall buildings also increase the effectiveness of natural ventilation because wind speeds are faster at greater heights. This improves not only cross ventilation but also stack effect ventilation. If your buildings are tall, natural ventilation is more effective. The higher you go, the wind speed is much more better as well. As you can see, if it is a tall building, the area exposed to sunlight is less and the area exposed to wind is more. If your building is designed in a such a way, the roof is exposed to higher solar radiation and the walls are exposed to less wind. This will create thermal discomfort. Tall buildings improve natural ventilation and in lower latitudes reduce sun exposure.

Orientation Strategies for Passive Cooling - Buildings should be oriented to maximize benefits from cooling breezes in hot weather and shelter from undesirable winds in cold weather. Look at the prevailing winds for your site throughout the year, using a wind rose diagram, to see which winds to take advantage of or avoid. You'd observe here, this is a windrose pattern in which it indicates to us which side has good wind and wind speed when compared to one another. From this type of windrose pattern, you can orient your buildings according to your wind direction to get benefited out of natural ventilation.

Generally, orienting the building so that its shorter axis aligns with prevailing winds will provide the most wind ventilation while orienting it perpendicular to prevailing winds will provide the least passive ventilation. If your prevailing wind is towards the west direction, you need to create openings towards the west to benefit from natural ventilation rather than keeping your windows on the north or southern direction.