Climate and Built Environment
Lecture 7

Wind

Wind is simply the flow of huge amount of air, usually from a high pressure-area to a low-pressure area. As you can see in the picture below, there is the main source i.e Sun, the one that heats up the air. There is a high pressure zone that is created. There is a less heated up area which is created as a low pressure zone and the air from the high pressure zone moves to the low pressure zone which is called as wind. How are winds formed? Typically this begins with the sun's radiation, which is absorbed differently on the earth's surface. The Earth's surface is heated differently because of the scenarios like cloud cover, mountains, valleys, water bodies, vegetation and desert lands.

Due to the presence of different topographical regions found on the Earth's surface and the fact that some of these places are hilly, valleys and not flat surfaces, the amount of radiation absorbed by the land is different. It is due to the topography and the material that is present over the landforms. Due to this difference, the air that is present above these topographical places gets heated up at different timings because of which high pressure zones and low pressure zones are created. Then the air moves from high pressure zone to low pressure zone which is what is felt as the 'wind'. As a result of this uneven heating, there are bound to be Earth surfaces that vary a lot in terms of temperature. Air of surfaces with higher temperatures will then begin to rise because it is lighter i.e less dense. As the air rises, it creates low atmospheric pressure. Air on surfaces with cooler temperatures sink i.e they do not rise. What do they mean by cooler temperature? If you notice the air just above a water body, such as a river or a lake, the air is much cooler. Where the water body and land begins, there is a difference in the two types of topography and the land form. One is the water body and the other a landform. Due to these differences, one creates a cooler temperature, one gets heated up much faster which is the land and the air starts to move. The sinking creates higher atmospheric pressure. This behaviour of warm gases or liquids move upward and are replaced by cooler particles called Convection. The energy moving during convection is called conventional current.

Important - hot air rises and cool air sinks. This brings about spatial differences in atmospheric pressure, caused by uneven heating. As we know, when the air is being heated up, the water molecule that is present in the air gets evaporated eventually and that becomes lighter which is hot air that rises above due to the reduction in the density of the air and the air which is cooler, which has more of humidity in it becomes heavy and it usually settles down.

Influence of Topography - Topography influences wind characteristics. Valley bottoms are generally wind protected areas whereas elevated locations receive more and stronger winds. As you can see in the image, the topography of the land has been showing large differences, this is a valley and this part is called a mountain. The differences between these heights, the land that is getting heated up at different rates because of which air tends to move from the place it gets heated up more to the place that gets lesser heated, that is higher pressure zones and lower pressure zones. As the name suggests, the two breezes occur along coastal areas or areas with adjacent large water bodies. Water and land have different healing abilities. Water takes a bit more time to warm up and is able to retain the heat longer than land does. As you can see in this picture, the water body ends and the land form starts. The water body has the ability to heat up less compared to the land form. The air that is present just above the land gets heated up faster compared to the air that is present above the water body. It is because of this difference in time which takes for the air to get heated up, the pressure difference is created and the air begins to move from the hotter region to the cooler region which is above the water body. The warm air rises and circulates here, this is the cool sea breeze that moves towards the land.

In the day, when the sun is up, the land heats up very quickly and the air above it warms up a lot more than the air over the water. The warm air over the land is less dense and begins to rise. Low pressure is created, since the water molecules present in the air just above the land gets evaporated easily and the air stars to move up because of which low pressure zone is created below the land forms.

The air pressure over the water is higher with cold dense air, which moves to occupy the space created over the land. When the air that is present above the land form starts to move closer to the water body, there is an empty space that is created just above the land form, to fill this void, the air that is present above the water body starts to move and fill this empty space. The cool air that comes along is called a sea breeze. When the cool air starts to move from the sea to the land, it is called sea breeze. It is much lesser in temperature and higher in humidity.

In the night, the reverse happens. The land quickly loses its heat while the water retains its warmth. Due to the specific heat capacity of water, it can hold the heat for a longer time when compared to the land, because of which the reverse process happens when the sun isn't present. This means the air over the water is warmer, less dense and begins to rise. This air moves from the landform due to the emptiness that is created just above the sea or the water body. The air above this landform starts to move to fill this empty space. Low pressure is created over the water. Cold and dense air over the land begins to move to the water surface to replace the warmer rising air. The cool breeze from the land is called a land breeze. These are two different types of breeze; sea breeze and land breeze.

Built Form and Air Movement

Moving on to Built form and Air movement. As we observe in this picture, the air moves from positive pressure to negative pressure zone, that's what happens even in elevation or plan. This is important for us to reduce the wind shadow. Wind shadow effect is the absence of wind. As you can see in this picture, the air starts to move from positive pressure to negative pressure. Due to the presence of a built form the air path has been changed like this. There is a small zone that has been created just near the built form and that does not receive any wind. That point is called as wind shadow. As you see, there are different organisations which are creating different types of wind shadows, these oranges are marked as wind shadows or negative pressure zones and the wind moves from the positive pressure zones to negative pressure zone.

When the large built volumes, or say a long row of buildings placed perpendicular to the wind direction, the shielded zones are established between the buildings, where wind speed might just be a small fraction of speed above the building's roof or in streets parallel to the wind direction. In this case the distance between the buildings have a little effect on the speed currents between the buildings, the first row of buildings divert the approaching wind current upwards, the rest of the buildings are left in wind shadow. If you are keeping a very tall building on the prevailing wind direction and then placing smaller buildings, all these smaller buildings will be left in wind shadow i.e there will be no wind for the smaller buildings. If the smaller buildings fall on the side of the prevailing wind direction and the taller buildings go much further, the wind can be diverted and be made to rise above and it can still be beneficial for the taller and shorter buildings. Thus, two separate air flow regimes are created. The regional air currents flow mainly over the top of the buildings while in between the buildings a secondary air flow pattern is created as a result of the friction between the upper air currents and the building. As we know, the building is a 3d form. One part of the primary air current starts to move above the building and there is one part of the building that moves horizontally which is around the building and it benefits around the ground cover. This may be desirable in certain climatic conditions like the col winters or hot summers when winds are to be avoided. Depending on the climatic condition, like the cold climatic condition, you would not prefer the wind to breeze against your body because it would further drop down your psychological equivalent temperature. To reduce that effect, you need to block the wind. If you are designing for a warm humid climate, you need constant wind movement across all your spaces to take away the humidity present in the air but this is undesirable in warm humid climates when ventilation is required.

On the other hand when building blocks are placed parallel to prevailing wind direction, the wind can blow through spaces between the buildings and along the streets with smaller effects

from friction with the buildings. In this case, the interior of the buildings suffer from poor ventilation while the adjacent open spaces experience high wind velocities. If you are placing your buildings parallel to the prevailing wind direction, then the wind that is going to come is going to be beneficial to the open space that is around the building but not for the interior spaces. The interior spaces are going to be more like wind shadow, going to lack wind speed while the open spaces are going to have higher wind speeds. Depending on the usage pattern, if you are designing a building that is going to be occupied for awhile, you need to change the scenario. But if you are going to design an open space, just a small supporting structure that is going to be used very minimally, you can actually allow the building to be parallel to the wind direction.

Orienting buildings at an angle are in relation to the wind direction that can produce relatively homogeneous wind patterns around them. Thus, creating better ventilation, regardless of the relative position of buildings within the built in arrangement. There are some architectural modifications that can be done to facades, they can divert the prevailing winds to the interiors of the building, making it beneficial for both outdoor and indoor spaces.

As we have learned, all airflow is the result of pressure differentials. There are few main ways in which this occurs in relation to buildings. Wind pressure where the exterior air flow creates high and low air pressure zones on the building and stack effect in which heat rising within the interiors of the building seeks to escape and draw in cooler air. Wind pressure acts on a building in two major ways, the first and most commonly used is cross ventilation. The second is Venturi effect.

The air that is moving is mainly due to pressure difference. The wind moves from positive pressure to negative pressure because of the difference in surface heating. The hotter air starts to rise up and fill the void that has been created because of the hot air rising up. This effect is called 'stack effect'.

All airflow is the result of pressure differentials. Wind pressure is the result of air blowing against or past a building. If you look at this building, there is positive pressure and these are negative pressure zones which means the wind is flowing from the positive direction and is going to go to the negative pressure zone. Pressures on the building surfaces come from the change in momentum when air is deflected or its speed is reduced. Positive pressure is created on the windward side and negative pressure on the leeward side, resulting in air flow from positive to negative pressure zones. The direction of the wind that is moving is called windward side and the direction that has no wind is leeward side. Hence, you need to orient your living spaces towards the windward side and you need to orient your spaces like staircases, toilets and the staircases that are very minimally used towards your leeward side.

Orienting with the long axis perpendicular to the prevailing warm weather breeze helps produce the greatest pressure differentials. Due to the heating of spaces, the solar chimney can be heated up and then the pressure difference can be created within the building and the air can be made to move from the solar chimney to the lower or the cooler side of the building.

Cross Ventilation

When placing ventilation openings, you are placing inlets and outlets to optimize the path air follows through the building. Windows or vents placed on opposite sides of the building give natural breeze a pathway through the structure. This is called cross-ventilation. Cross-ventilation is generally the most effective form of wind ventilation. What cross ventilation means is, you are creating an opening towards the prevailing wind direction, which is the inlet and another opening that's just opposite to your prevailing winds. So, you are making the wind to move from one end of your room to the other end, because of which ventilation is going to cover throughout the room. This system is called cross ventilation.

As we see, there are single openings, two openings on the same, two openings for the winds, two openings - adjacent walls and two openings for opposite walls. We cannot keep two windows opposite each other in all scenarios. In some places there might be other rooms adjacent to your room, avoiding the presence of two windows exactly opposite each other. In those cases, there are other types of ventilation systems that can also be used beneficially. The architecture facade can be modified, say in the case of 'two openings with wings', in which they offer smaller projections which are from the external facade which is going to divert the wind to leave. These are some of the modifications that can be done depending upon your design - Cross ventilation (bottom images is more effective than ventilation that does not pass through the whole space). If your design is giving you an opportunity to use two different walls for openings, it is considered to be the best type of ventilation system since the air can move from one end to the other end, which covers the whole room compared to the other opening systems present here.

Placing inlets low in the room and outlets high in the room, can cool spaces more effectively because they leverage the natural convection of air. As you can see, in these images on the right, there are openings present on the higher side of the room or on the lower side. The red depicts the hot air, only the hot air begins to move and the place becomes much cooler. Here the cool air comes and the cool air is taken away immediately. The rest of the room is left hot. However, when you keep a higher window opening and a smaller window opening on the other end, cooler air is drawn from the lower end and the hot air that is rising above will be taken out by the higher winds.

Cooler air sinks lower, while hot air rises; therefore, locating the opening lower outlet that helps push cooler air through the space and locating the exhaust high up, will help pull in warmer air out of the space.

Steering Breeze - not all parts of a building can be oriented for cross-ventilation. But wind can be steered by architectural features such as casement windows, wing walls, fences, or even strategically-planted vegetation. Architectural features can scoop air into a room. Such structures facing opposite directions on opposite walls can heighten the effect. These features can range from casement windows or baffles to large-scale structures such as fences, walls or hedgerows. As we saw, all buildings cannot be oriented towards prevailing wind. Imagine if there is a structure that is blocking the wind from reaching your end. Hence, you need to plan your architectural forms in such a way that keeping your baffled walls or keeping fences or even vegetation can promote diversion of the windflow. You can divert the wind that is headed to your direction and make it come inside your interior spaces to talk away the stale and hot air.

For instance, this is the prevailing wind in this image but the building has been designed here with two small windows. There is a small wall which is being projected outside. As the prevailing wind hits this wall, it automatically gets diverted inside and the air moves inside in the whole space. The air that is being used up gets moved out as well. In warm and humid climate, the prevailing wind direction changes every 6 minutes. This will be beneficial for the remaining 6 months as well where the prevailing winds will move in the opposite direction. At that point of time the prevailing winds will be in this direction and due to the presence of the wind wall , it will get diverted inside here and the used up air will be taken up here. This is how architectural modifications can be done to enhance the natural breeze from within your space. Building structures can redirect prevailing winds to cross-ventilation.

Wing Walls - these project outward is next to a window, so that light can breeze against the wall creating a high pressure zone on one side and lower on the other. There is one small projection on one side of the wall. When the air begins to the hit the wall that is called the wing wall, a high pressure zone is created and because no wind is present on the other side of the building, that becomes a low pressure zone. Hence, the wind begins to move from the high pressure zone to the low pressure zone. The pressure differential draws outdoor air in, through one open window and out the adjacent one. Wing walls are especially effective on sites with low outdoor air velocity and variable wind directions. If your site is located at a space where the wind speed is very low or the prevailing wind changes quite often, you can then go for wing walls which can be used to divert the wind and enhance the wind speed.

These are some of the best orientations for the wind wall to be located, these are apertures or openings located on the same wall. If your design uses apertures on the other side of the wall,

these are two different and best types of orientation. The others or the wing are also positioned very close to each other because of which there is a lot of space left without air movement. You need to keep your wing walls in such a way that the air starts to move, rather than leaving wind shadows within the room.