Energy Efficient Architecture
Lecture 6

Induced Ventilation

Passive cooling by induced ventilation can be most effective in hot and humid climates as well as in hot and dry climates. This type of system is mainly used for extreme conditions , hot and humid; hot and dry that's usually present in tropical regions. This method involves the heating of air in a restricted area through solar radiation, thus, creating a temperature difference and causing air movements or drafts. This is by heating up the air, increasing its temperature because of which the air will get lighter, move up and will invite the cold air to come in. This is by creating a draft in which cooling can be achieved. The draft causes hot air to rise and escape to the ambient, drawing in cooler air and thereby causing cooling. In effect, a solar chimney is created to cause continuous air circulation. A solar chimney will be looked into later. This is a tall tower present to enable effective induced ventilation systems. Systems like wind tower is also an example for induced ventilation in which the heated hot air will rise up and will escape through the openings present in the tower and then due to the emptiness that is present in the space, cool air will automatically come in and it creates a draft, a constant flow of air through our body.

Variations and Controls. Arrangements may be made to draw air from the coolest part of the structure as replacement to set up a continuous circulation and cool living spaces. This is how it is being made and you need to keep your openings or apertures depending on where the air has to flow in, the wind direction, the wind pattern, depending on which the air can come in through the direction that's present in your climatic region in your area of design. Curved roofs and vents are used in combination for passive cooling of air in hot and dry climates, where dusky winds make wind towers impractical. When you observe places like deserts, the wind is usually very dusty, to avoid this the top of the wind tower is made into a curvy structure so that the dust present in the air does not enter, gets filtered and only air can enter through this. The system works on the principle of cooling by induced ventilation caused by pressure differences. Due to the pressure differences created by the hot air and the cold air, it creates a pressure difference due to which air can be drawn constantly inside the living spaces. As you can see, these openings are made according to the windflow patterns. This is a positive pressure and a negative pressure. Usually the air moves from a positive pressure to a negative pressure when we can feel the air being moved or feel the cool of the air that's passing us. To create this effect as to why are we doing such openings and creating this system, it is called induced ventilation. This is the induction effect in which we are creating a flow of air inside the space but this is a Suction effect in which the positive pressure has been closed here and only the suction, the hot air used in this space can go up and can open up and it escapes through the outlet that's

present here. This is suction effect and this is the induced effect. When there is no wind that has been blowing, you can use the induced effect. When there's good wind blowing you can make your openings act as a suction control.

Wind Flowing over a curved surface creates a pressure difference across it. If vents are provided on the surface, air is sucked out of the structure through the openings. If there is a curved structure, when the wind passes through a curved structure, it cannot come inside and usually it gets diverted due to the shape of the structure. If you want your windows to effectively draw winds, the windows have to be made flat and this opening of making the roof or the curved dome will be effective only for hot and cold climatic conditions only which air is very dusty. Therefore, the hot internal air forced its way out through the vents inducing air-circulation. Air vents are usually placed above living rooms. This type of curved openings are usually present above the living room's only where the suction is happening in which hot air is just escaping outside. This is the diverted effect in which we need air to flow through one space and air to suck it out through the other opening and this is Chimney effect in which hot air rises and both the openings can be used to take out the hot air because the air is going to come through the lower openings. It depends on different climatic conditions and different windrose patterns. This type of suction or chimney effect can be used depending on your climatic conditions. The combination of two or more.

The Principle - Curved roofs and air vents are used in combination for passive cooling of air in hot and dry climates, where dusty winds make wind towers impracticable. Suited for single units, they work well in hot and dry and warm and humid climates. As we just saw, it can be this curved structures, wind towers and induced ventilation systems are usually much more effective when it comes to hot and dry climate where the wind is usually dusty and also for climates such as hot and humid climatic conditions, the climatic condition we observe in the tropics. A hole in the apex of the domed or cylindrical roof with the protective cap over the vent directs the wind across it. The opening at the top provides ventilation and provides an escape path for hot air collected at the top.

When it is a very dusty wind condition, you use a wind tower and the cap of the wind tower is made into a curvy form. As you will observe here, the cap in this tower is being made into a circular form because of which the wind that passes through gets diverted because of the shape and doesn't enter in. It only makes the hot air being used within the space rise above and due to the opening present here, it takes it out due to the suction effect. Also, due to the form of this tower, it doesn't allow the wind that is present around the structure to come inside. Arrangement may be made to draw air from the coolest part of the structure as replacement, to set up a continuous circulation and cool the living spaces. If you have a plantation or a water

body, you need to keep your openings in such a way that, the cool air can come into the living spaces by passing through such water bodies or vegetation which cool the primary air source and the ambient temperature reduces. The system works on the principle of cooling by induced ventilation, caused by pressure differences. To summarize it works on the principle of pressure difference which is created by solar heating with increased pressure on one side that has moved up and sucked out because of the presence of openings on the towers. Due to the pressure difference created the cool air is automatically drawn inside through the lower openings or windows.

Earth Cooling

Moving on to Earth Cooling/ Earth Sheltering. The Earth under and around a building can serve in many climatic regions as a natural cooling source for the building, either in a passive or an active way. It is possible to lower the Earth's temperature within a confined area well below its 'natural' level, by eliminating its heating by the sun while enabling evaporation from the Earth's surface. When you see this Earth cooling or Earth sheltering can be used for a wide range of applicability rather than our evaporative cooling that can be confined to certain climatic conditions, certain systems can be used and you need to modify a system completely to adapt to your zone of climatic condition. This Earth cooling and Earth sheltering can be beneficial for a wide climatic range, this can happen either by sinking a whole building inside the Earth or by making Earth elevated. This can use the cooling that's present in the natural ground and cool the temperature around your building. To draw the cool air around it and use it within your interior spaces. As you'd observe in this picture, the air from outside is being drawn in and is being made to pass underground. Obviously below the ground, certain levels, the temperature of the Earth remains constantly throughout the year. There is no variation for climatic or between morning and night or other such variations do not affect after a certain level under the ground.

This can be used in climatic conditions in which the air is being made to pass through the tunnel and here the ground is at a constant temperature, the air that is present inside the tunnel automatically lowers the temperature and cool air is being drawn inside, this space is being used. You can further have water bodies like fountains or any other vegetation which can further reduce the dry bulb temperature of the primary air stream that's being passed through the tunnel. This cool air can then be transferred to various spaces within the building. The used up hot air can rise above and escape through much higher levels. Two methods have been tried to lower the Earth's temperature. Rising the building off the ground and encouraging evaporation from the surface either by irrigation or by feeding summer rains into the area below the building. This first system is by elevating the building above the ground and by using

water sprinkling systems or by making your surrounding Earth completely wet all the time. This can in turn help in maintaining a constant temperature. This can help your primary source which comes in through under the Earth pipes, can help reduce the temperature. Covering the soul with a layer of gravel, at least 10 cm thick and in regions with dry summers irrigating it. These are the two different types that have been happening. One is completely sinking a building into the Earth or elevating the Earth around your structure and using water bodies to cool the Earth present around. Pipes can be used around it according to the climate.

Expected Performance

Experiments in Israel and the USA (Arizona and northern Florida) have demonstrated that it is possible to lower the Earth's surface temperature by approximately 8 degree Celsius to 10 degrees below the summer temperature of exposed soil. According to the researches being made in conditions like Israel which have prolonged hot and dry seasons, it's been shown that the Earth's temperature can be reduced from 8 degree celsius to 10 degree Celsius. This is obviously going to contribute to the cooling of your air that is going to get circulated into your interior spaces. As you observe here, the outdoor temperature fluctuates from morning to evening. This is for a typical winter day but this dark line as you can see here is the indoor temperature which is constant because no fluctuation is going to happen on a daily basis under the Earth. Since we are making air pass beneath the Earth's surface, it will be beneficial to use the Earth in both winter and summer season because the Earth maintains a constant temperature throughout the year. The difference between the 'treated' and 'untreated soil' is reduced with depth, reaching about 60 degree Celsius at a depth of 60 cm. The difference between the outdoor maximum temperature can be to about 15 degree Celsius in mid-summer, providing the potential for a heat sink for the building.

Until the depth of 60cm from the surface of the Earth, the temperature difference can be achieved, the Earth can maintain a constant temperature. Even if you go further down, the temperature is going to be constant throughout. It's usually ideal to have tunnels just below 60 cm because even if you place it further below, it is not going to contribute to any further passive cooling or heating effect. This is a research based on Israel as well. You'd notice how above ground house, it has a daily fluctuation or seasonal fluctuation is being observed. This is for a place below the equator in which the months in summer i.e between November to February, this has a peak summer but the Earth shelter houses maintain almost constant temperature and there's almost 10 - 15 degree Celsius in temperature which is very good of an overall year performance.

Wind Towers

Next moving on to Wind Towers. These are some of the wind towers that's being used over the years. In a wind tower the hot air enters the tower through the opening in the tower, gets cooled and thus becomes heavier and sinks down. This uses the same principle as Induced ventilation system. Wind tower is one of the elements that uses the physics of induced ventilation system. The hot air enters the tower through the opening in the tower, gets cooled and sinks down. The inlet and outlet of rooms induce cool air movement. In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living area. As you observe, this is the wind tower, this is a wet screen, there is a water tank above it. The air that is passing through will be made to get inside due to the presence of the water body above the tower and there is a presence of a wet screen which lowers the temperature of the air that is to come inside. This air comes here, cools down and due to the heavier weight of the air, because of the additional relative humidity that is being made due to the presence of wet screen, the heavier air is drawn down and circulated throughout the house. The hot air escapes through normal aperture openings like windows and doors. This is the same induced ventilation concept but it is being used in a reverse way by cooling the wind at the primary source at a higher level and letting it escape in the lower level. After an entire day of air exchange, the tower becomes warm in the evenings.

During the night, cooling ambient air becomes in contact with the bottom of the tower through the rooms. As you observe, this is how the tower is being protected from entering any solar further solar radiations and after a whole day of heat exchange, this tower becomes very warm in the evening. There are usually openings present in the wind tower at regular intervals. During the night it can be opened up completely. Due to the difference in temperature at night when compared to day since its much cooler in the former, this is observed in the walls of the wind tower. It is because of all these openings, the heat can be left to escape in the day time. This is much more effective when there is good diurnal variation present in your climatic zone. When your morning temperature is very high like 40 degree Celsius, when the temperature at night is very close to 10 or 15 degree Celsius, this becomes much more effective.

This image is building-integrated chimney in a residence that's present in New Delhi from effective ventilation especially during humid season. This is one of the case study that we have found for a wind tower that's present in New Delhi. The tower walls absorb heat during daytime and release it at night, warming the cool night air in the tower. This is by having the openings in the wind tower that can be opened up at night. Warm air moves up, creating an upward draft and draws cool night air through the doors and windows into the building. Since the air is being let out, it creates a draft causing the cool air to be brought down and then it again has to circulate in the living areas allowing the hot air to escape. The system works

effectively in hot and dry climates where fluctuations are high. In areas like Rajasthan, Jaisalmer where temperatures can vary drastically from morning to night, this type of wind tower becomes much more effective even in places like Hyderabad. This is a picture of a wind tower, how we have openings and how it sucks in the air made of mud, cools the primary air and is a good thermal mass. This absorbs and prevents the daily fluctuations that have been happening. A wind tower works well for individual units not for multi-storeyed apartments. This is one of the disadvantages. It can be restricted or adapting this system for buildings which is single unit but when it comes to multi-storey buildings or an apartment or a commercial complex this system is not as effective as it is in individual units. In dense urban areas, the wind tower has to be long enough to be able to catch enough air.

If you are designing a dense urban area, all the buildings around you will be so tall that it will restrict the flow of wind to your wind towers. You need to choose your height of the wind tower depending on the locality in which you are going to design. Also protection from rain is difficult. Since we have a lot of openings in the wind tower, protecting it during the rain can also become a little messy.

Next is Courtyard effect, these are some of the images in which, in a building you have a small opening for a passive cooling effect, this is called a courtyard. Due to the incident solar radiation in the courtyard, the air gets warmer and rises. The 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. We must have observed in courtyard houses, huge sunshades and louvered panels which are being projected out to protect our interior spaces from direct incident solar radiation. This is usually located in rooms surrounding the courtyard. We have openings in our rooms, which draws the air and the used up air becomes hot and due to the reduction in relative humidity compared to the primary source, the air becomes lighter and it rises above. Due to the opening in the presence of the courtyard, this makes the air escape outside from the central opening which creates a draft again and again the air gets sucked inside because of the pressure difference that has been created due to the presence of the courtyard.

If this heat exchange reduces roof surface temperature to wet bulb temperature of air, condensation of atmospheric moisture occurs on the roof and the gain due to condensation limits further cooling. As we see, these are different levels of protection being made at the courtyard for the interior spaces. The courtyard has been modified in such a way having different levels of protection. Even through the day, even when the sun is at lower angles during the changes from winter to summer, the interior spaces are being completely protected, because of such type of design articulations that you are making. If the roof surfaces are sloped

towards the internal courtyard, the cooled air sinks into the court and enters the living space through low-level openings, gets warmed up and leaves the room through higher-level openings. Here, as we see there is a pool that is present in the centre of the courtyard. Due to the presence of the pool, what happens is the air that is being entering inside gets cooled because of the evaporative cooling system which is a pond and that gets circulated around this space. It gets used by occupants who are going to move into the space. The halt air which is being used by the occupant is going to rise above and due to the presence of this type of opening which is very close to the roof, the hot air escapes outside. However, care should be taken that the courtyard does not receive intense solar radiation, which would lead to conduction and radiation heat gains into the building. When you're sketching your courtyard sizes and dimensions, you need to be sensible enough to choose a proportion where your courtyard is not too big to invite instant solar radiation or very narrow to be cold during winter seasons. The proportion has to be very ideal depending on the climatic location, which you are going to choose. Even if it has extended the summer period and is a more of a humid location, you need huge openings and protect your walls from direct solar radiation. For which, we can typically use water bodies or trees as shown in the picture. This space becomes very active due to the presence of vegetation and the temperature has been bogged down due to the presence of a tree. The tree also evaporates humidity to the air which causes the space to become more comfortable even though it is a huge opening during a summer day.

Next is Earth Air tunnel. Although, this technique is essentially used for cooling the air in hot and dry climates, it can also be used for winter heating. Earth-air tunnels may be considered as special types of wind towers connected to an underground tunnel. Earth Air Tunnel is the tunnel which is connected to your underground, draws the air from outside. Its being circulated below your ground and circulated to cool your building. A wind tower is connected to the underground tunnel, which runs from the bottom of the wind tower to the basement of the building. In some places we can connect the Wind tower and the Earth air tunnel as well to further reduce the temperature, it is a combination of two systems.

Case study - This technique has been used in the composite climate of Gurgaon in Retreat building. The living quarters of the south block of Retreat are maintained at comfortable temperatures, approximately 30 degree Celsius round the year by the Earth air tunnel system. The technique has been supplemented whenever required, with a system of absorption chillers chillers powered by liquefied natural gas during monsoons and with an air washer during dry summer. As you can observe, this system is used in a composite climate in which you have summer and winter, a high variation between the two.

It is because of these variations, you can observe almost 60 cm below the ground's surface the temperature is being constantly maintained between 20 - 30 degree Celsius which can be brought into your interior spaces and used throughout the year. This can help reduce the use of mechanical cooling systems. This is the tower which is connected to the Earthen system. The Earthen system is where the air is being sucked in and there is a fan room which cools the air. Its being conditioned here and this air is being transferred to different parts of the building by the presence of a wind tower. This is the solar chimney which is protecting from any further type of direct instant solar radiation and it is just taking out the used up hot air and it is letting it go. Two blowers installed in the tunnels to speed up the process. The same application supplies warm air from the tunnel during the winter.