

**Course Name: Bioclimatic Architecture: Futureproofing with Simple and Advanced Passive Strategies**

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**Lecture 01**

Passive down draught evaporative cooling,

Hello everybody. So, we had been seeing a series of advanced passive techniques, some of which are heating techniques, some of which are cooling techniques, and some of which can be used for heating as well as cooling. Say, for example, the roof pond treatment that can be used for heating purposes as well as cooling purposes. Today we will see another interesting advanced passive technique, and that is PDEC, passive downdraft evaporative cooling. Now, what is passive downdraft evaporative cooling? The concept of passive downdraft evaporative cooling can be traced back to the classical architecture of the Middle East, which included wind towers, wind catchers, or wind scoops to create natural ventilation within buildings. These towers are referred to as Malkov in Egypt and Boudgir in Iran and Iraq.

So, the inspiration for PDEC is actually vernacular architecture. According to Bernoulli's theory, these towers rise above building roofs and draw air into the interior through pressure differences caused by wind blowing over wind scoops and the building. PDEC uses a direct evaporative cooling system that uses the adiabatic humidification principle to cool the air at the top of the tower. The down draft air flow depends only on buoyant forces in the absence of wind.

In this instance, it is necessary to use fans to enhance their distribution. This can be integrated with dehumidifiers if this has to be used in a hot, humid climate. Otherwise, it is a technique that is primarily used in dry areas. So, you can see that the passive downdraft evaporative cooling system has a tower. So, the inspiration for these towers with their outlets is vernacular architecture.

Sometimes when there is water, droplets are added to increase its moisture. We will see this in detail in the forthcoming slides. The tower wall's thermal mass, which consists of bricks or stones, allows for sensible heat exchange to partially cool the air. Additional cooling is provided by evaporation in ponds and fountains that are positioned at the outlets

of the tower. The practice of chilling air at high altitudes such that it descends down to a lower area by gravity because it is heavy is known as passive downdraft cooling.

So cooling systems are commonly classified based on how they produce a down draft. Misting nozzles, shower heads, wetted pads, porous media, chilled water pipes, and hybrid systems are some of the methods through which the air is made heavier by increasing its humidity. So, in general, there is a tower, and this tower has a thermal mass. When solar radiation strikes it, the air in the tower becomes warm too. Now in order to add humidity to the air inside the tower.

There is sometimes rigid media here. There is a rigid medium here that makes the air moist, or sometimes there are misting nozzles that spray water, and the air that flows here becomes moist. When the air flows here, it becomes moist. And because of the weight, it comes down. The air flows down.

Sometimes there are shower heads that throw water. And of course there have to be collectors below. Here and here. Everywhere there has to be collectors. Sometimes there can even be chilled water.

Pipes. So air gets chilled. Air that passes through this gets chilled by contact with these pipes. Sometimes there are misters that cause mists. As seen in case I, we will number these cases A, B, C, D, and E. So, this is a combination of B plus C; that is what this is a combination of.

So, we have the misters as well as the chilled pipe system. So, when air flows through this, it becomes cooler, and of course, there has to be a collector in this case below. This is the working of a PDEC. So, if you look at the taxonomy of a downdraft cooling We have the passive downdraft evaporative cooling, active downdraft evaporating cooling which uses chilled water coils or panels like how we had seen in the previous slide. If you remember this, the chilled water pipes, these become active downdraft evaporating cooling, or sometimes panels, and drive air over evaporative cooling pads directly into the building.

There is a hybrid downdraft cooling, which has the coils in the upper portion of the enclosure using two stages of cooling. You have active downdraft as well as hybrid downdraft cooling. These are alternatives to conventional air conditioning because energy is consumed through a mechanical system for cooling the air, and fans are required for air circulation. So, here you have an inlet through which wind flows. So, there are these inlet slits or openings, which is located at the top of the tower And then there is a system which could add mist or humidity, which makes the air heavy.

And the heavier air, which becomes cool, flows down and enters the room. Here in this picture, you can see that there is a combination of multiple advanced passive technologies. There is a PDEC passive downdraft evaporative cooling. Then there are radiant ceiling panels, which we will be studying later. Radiant ceiling, and there is a trombe wall for heating, which again we will be seeing in another class, and there are PV panels. So, this demonstrates that multiple advanced passive techniques can be used in a single building to achieve the desired result. Now, what are the conditions required for passive downdraft cooling to work? First, the climate has to be primarily hot and dry. So, dry climates are a good fit for evaporative cooling systems. Because of the increased evaporation rates, evaporative cooling requires a dry atmosphere.

The process of evaporation would take in heat and provide a cooling effect in the surroundings. As opposed to the hot and dry atmosphere, areas with low temperatures are also favoured since there is less of a difference between the ambient temperature and human comfort levels. This would result in less cooling demand and energy savings. Let us look at the application. Now evaporating cooling systems, these are appropriate for use in commercial, industrial, and residential buildings.

They work best in large open spaces that promote air flow. The circumstances of the site determine how well evaporative cooling systems integrate with other active systems. Humidifiers to preserve humidity and filters to clean contaminated air must also be used and incorporated. Let us look at the architectural design required. Because of the exposed shaft, the installation of passive down-trap evaporating cooling towers may have an impact on architectural aesthetics if it does not match the taste of a designer.

The layout of underground rooms would be impacted by the installation of evaporative cooling shafts. Water bodies must also be provided, and these need to be taken into account in the overall construction design. As compared to traditional cooling systems, the initial building cost is often greater due to the requirement of creating an additional tower structure and a system. But if we look at the benefits over the long term, this greatly lowers the operating costs. If we look at direct evaporative cooling, then in terms of architectural design, we need to have lots of openings to allow the air circulation.

If we look at indirect evaporative cooling, there is no effect on the architectural design. Whereas in passive downdraft evaporative cooling, expressive architectural form with a vertical shaft can be prominently seen, which we will also see in our case studies. Underground evaporative cooling may affect underground space design, and if mist is used or water bodies are used, these can be used as landscape design or incorporated on the facade of the building. When it comes to cost, passive downdraft evaporative cooling has a higher initial cost. In fact, all these techniques, which are advanced passive techniques,

incur additional cost because there is a need for a separate contraption in order to get the desired results.

Let us now look at the basic working principle of PDEC. The passive downdraft evaporative cooler requires water saturation. So, water is brought into contact with a medium, which is typically a porous material like a cellulose pad or evaporative cooling pads. These pads are often installed in a vertical configuration in cooling towers or even in air handling units.

Then air flow is required. Warm and dry outside air is drawn through the wetted pads by a natural or induced draft. This can be achieved through the use of wind, natural convection, or mechanical fans. Third is evaporation. As the dry air passes through the wetted pads. Through the wetted pads by a natural or induced draft.

This comes into contact with the water-saturated surface. The dry air absorbs moisture through the process of evaporation. Causing the water to change from liquid to vapour. This phase change requires heat, which is extracted from the surrounding air, leading to a reduction in its temperature. So the air that comes out is cooler.

The temperature of the air is significantly lowered as a result of the evaporation process. The cool air is then introduced into the conditioned space, providing a comfortable and cooler environment. In passive down-draft evaporative cooling systems, the cold air tends to sink due to its increased density compared to the warmer air. This creates a natural down draft effect when the cold air descends and displaces the warmer air at lower levels. These towers are often described as reverse chimneys.

While the column of warm air rises in a chimney, in this case the column of cool air falls. Key factors influencing the effectiveness of passive down-draft evaporative cooling. First is the relative humidity. PDEC works best in low-humidity environments. In areas with high humidity, the air has limited capacity to absorb moisture through evaporation.

So, if we have a tower with a slit, then the air that comes in actually absorbs the moisture, and unless the air is dry, it will not be able to absorb the moisture. Air that is already laden with moisture cannot absorb more moisture, and therefore this system is most appropriate in dry areas and dry climates. The second is air velocity. Adequate airflow is crucial for effective cooling. The speed at which air passes through the wetted pads determines the rate of evaporation and consequently the cooling effect.

Water quality is very important because we are talking of dry areas that have water scarcity. The quality of water used in the system can impact the efficiency and maintenance

requirements. Clean water is essential to prevent scaling, and also clogging of the wetted pads. The system design is important because proper design of the evaporative cooling system, including the size and the type of pad or the type or the source of the moisturizer, including how well it is designed, and the layout of the air distribution system are all critical for optimal performance.

The air flow rate depends on the efficiency of the evaporative cooling device. Tower height and cross section, as well as resistance to air flow in the cooling device, the tower, and the structure, if any, into which this gets discharged. This entire system must be well designed and thought of comprehensively, as shown here. So, you need to have adequate wind pressure; you need to have a down draft, which happens when you have absorption or moisture pads. I will say moisture source could be pads or nozzles with good water quality and the wind pressure based on that comes and then there has to be a good collector of the extra water that comes from the mist. The air becomes heavy, and there has to be an outlet.

From the outlet, the air gets in. Because of the heat gain from occupants, people, equipment, and lighting loads, the air becomes warm, and there has to be a provision for this warm air to escape. And this is the process of and working of a PDEC. Let us now look at some case studies where this PDEC has been used. The first case study we will see today is the PDEC, which is used in the IGP building at Gulbarga. So the climate of Gulbarga has a rainy season, which is oppressive and cloudy.

But it has a dry season, which is often clear and hot for a long period of time. The average annual temperature ranges from 18 to 40 degrees centigrade and seldom falls below 15 or rises beyond 42. So March to May is the hot season, with an average daily high temperature of 38 degrees centigrade. This lasts for about 2 months. And May is the warmest month of the year in Gulbarga.

Because the average temperature itself is 39 degrees centigrade. So there is every chance that the maximum temperature is much higher. It goes to around 45 degrees. And the low temperature is 27 degrees.

July to January is a cool season. But still, the average temperature is 32 degrees Celsius and lasts about 7 months. If we look at the building, the IGP building is a ground plus two-story structure to house the Gulbarga IGP's office. There are many other simple and advanced passive techniques used in this building. Some of these are: the roof is composed of a filler slab that gives insulation. The exterior walls are composite walls made up of rat trap bond and granite facing on the outside.

So the view value of the wall is pretty much 1.53 watts per meter square kelvin. And the

roof U value is 2.15 watts per meter square Kelvin. The structure is rectangular in shape, basically as shown here. Evaporative cooling has been used because the building is situated in a hot and dry area.

PDEC towers are used to cool the majority of the workspaces, as you can see. the PDEC towers, which are located here. So, these are all the passive downdraft evaporative towers located in the IGP office at Gulbarga, which can be seen in the elevation. So, the PDEC system here basically consists of an open shaft with showers at the top.

So, here you can see water meters or water sprinklers. So, there is a cross-baffle wall here. Because of which this is prevented, the direct movement of air is prevented. The baffle wall ensures that the breeze that flows is directed down to the micronizers where the mist is sprayed. So and this water gets gathered below which is drained out. So, what happens is that at 11 am, the PDEC towers start operating.

They utilize these devices, resulting in a considerable percentage decrease in cooling electricity. So, through this mist, the dry air from dry warm air is directed to come down, and it absorbs the moisture and flows below. Again, there are baffle walls that direct the breeze inside. There is also a wood charcoal layer, which acts like a filter for dust, insects, and odour.

This cool air then cools down the room. Again, the remaining air that flows down gets into the ground floor. It is directed by means of a baffle wall here. So, it is said that at about 45 percent, the tower's thermal efficiency is increased because of the tiny water droplets. So this is a great method for providing thermal comfort in areas where electricity is also an issue. So, measurements were conducted in September 2005, which showed that the air leaving the tower is at least 4 degrees Celsius cooler than the surrounding air.

This happens on an average September day. You can see that the indoor temperature is at least 4 degrees centigrade. lesser lower than the ambient temperature. Also, you can see what happens in the other months. So if this is the ambient temperature, the temperature of air from the passive downdraft cooling is sometimes, depending on the month, 10 degrees to 15 degrees lower. So you can see that there is a temperature difference of 10 degrees centigrade in January and 15 degrees centigrade in May.

And of course, during the cooler months, there is a decrease in the temperature difference. So, there is a drop in temperature of 10 degrees Celsius in January and 15 degrees Celsius in May and June. and 5 degrees Celsius during the cooler part, which is around August, September, and so on. So, there is a considerable savings in terms of energy used to reduce the indoor air temperature in the IGP complex by use of the passive downdraft evaporative

cooling technique as well as the other techniques such as the rack trap bond, filler slabs, and so many other techniques. But this reduction in temperature happens in the passive downdraft cooling tower. So, by virtue of the passive downdraft tower, there is a reduction of 10 degrees centigrade in January, 15 degrees centigrade in the hottest part of April-May, 5 degrees centigrade in July-August and also 10 degree centigrade in November-December.

So, this difference in temperature between the ambient air and PDEC tower. Let us now move on to another case study, which is actually an old building that was built way ahead of its time, and that is the Torrent Research Centre in Ahmedabad. The three main seasons of Ahmedabad's climate are dry and hot from March to June, with daily relative minimum humidity below 20%. This becomes a 35-degree centigrade temperature between July and September, which is the monsoon season. The daily maximum temperature is 30 degrees Celsius, and the relative humidity is typically more than 65 percent.

During February to October, it becomes very cold and dry, chill and dry. The relative humidity is below 30%, and the maximum daily temperature is also below 35 degrees. During the month of May, it is extremely hot, with a mean maximum of 41 degrees Celsius. This is the most taxing season of the year. because there are frequent hot, dusty winds that accompany high air temperatures.

So, this is the background of the torrent research center. The torrent research center is a three-story open concourse with labs and offices, and it has, as you can see, a number of PDEC towers. So if you look at its design, assuming still air, the building's architecture makes it easier to create an air draft. Again, here the warm air flows through the grates and the openings on top and through moisturizers, and then the warm air becomes cool and it is diverted. into the building by means of diverters, which are placed here you can see.

There is a facility that diverts the air below. So, the concept is the same. So, how does this PDEC function during three seasons? During the cold season, this minimizes ventilation rates because there is no movement of air. The inlets are closed by shutters, and therefore, there is no air movement. Whereas, in the hot season, the micronizers get activated because the ambient temperature is 41 degrees to 43 degrees centigrade. Then, during the monsoon season between July and September, there is a maximum ventilation rate with micronizers.

So ceiling and wall fans are used to induce air movement in the same direction as natural flow. So, the airspeed upper limit is about 1.5 meters per second. By noon, all the exhaust gets closed in the monsoon season. So, because the climate of Ahmedabad has all three types of seasons, this is used effectively in the hot season and to some extent in the monsoon season.

Whereas in the cold season, the inlet is closed and blocked. So, from this, you can clearly see how the ambient air difference is there between the ambient air and between the air in the PDEC, just like how it is there in the IGP complex. So, you can see that this is the mean ambient temperature. And this is the temperature drop that happens because of the PDEC. The study has several conditions: what happens when the micronizers are switched on, what happens when the micronizers are switched off, but effectively you can see that there is a dramatic reduction in the ambient temperature by use of PDEC. So, we can see in this case study, which talks of, or rather, it is in this research paper, which talks of the significance of parameters that affect the performance of PDEC.

So, for a spray PDEC tower system, an acceptable range for the inlet air velocity throughout the cross section should be 0.75 meters per second to 1.5 meters per second. To improve performance, the system can efficiently handle the mass of incoming air that is dictated by the air velocity. So, the cross section of PDEC towers can be configured to be bigger than the area of a wind catcher, or the mass flow rate of the air passing through the system can be controlled.

The down draft evaporative cooling process can be completed by a spray PDEC tower system at an effective tower height that can be as low as twice or as high as three times the width of the tower cross-sectional area. So, the proportion or aspect ratio of the tower is also important, the wind speed is important, the wind speed at the inlet, the aspect ratio of the tower, then the presence or absence of micronizers or sprays, the inlet size, and the tactics used to divert the air towards the mist. So, all of these become important, and there has to be an outlet somewhere that is based on the design. So, all these aspects affect the efficacy or functioning of a PDEC. So, with this, we will stop today's class as we have seen the passive down trap evaporative cooling as a passive technique.