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

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Week: 08

Lecture 02

Direct Evaporative cooling

Hello students, in our last class, we saw an advanced passive strategy called as PDEC, which is passive downdraft evaporative cooling. In today's class, we will have a look at yet another technique called direct evaporative cooling. Let us see what direct evaporative cooling is. So, the direct evaporative cooling system is a well-liked model with an easy-to-understand design. The components of a direct evaporative cooling system, which I will call ECS, include a water distribution system, a wettable evaporative medium, a pump, a water tank, and a fan or blower. So, there is a cooling pad here.

There is a cooling pad on which water is sprayed. The mist falls and makes the pad cool. There is outdoor air, which is blowed and sucked in. which passes through the cooling pad, resulting in cooler air on the other side.

The water here through the cooling pad is collected. So, this system is more efficient and less expensive. The water and air in this ECS are in close contact with one another. The water is blasted as tiny droplets into the atmosphere, and these droplets transition from a liquid phase to a vapour phase by absorbing heat from the surrounding air. Because of the evaporation of water, this heat absorption lowers the air's temperature and raises its humidity, and this evaporation process is the adiabatic cooling process, and the enthalpy of the air remains constant during the process.

The water absorbs the sensible heat of the supply air, lowering the air temperature. The humidity of the air rises when water evaporates in the air stream. The ECS produces a considerable cooling effect, yet it consumes relatively little electricity as compared to a normal refrigeration system or an air conditioning system. This form of ECS is appropriate for both dry and hot areas. In a damp climate, the relative humidity may exceed 80%, which is not good for buildings since it may cause rusting of metallic components composed of iron.

Now, in direct ECS, the air temperature cannot be reduced below the wet pulp temperature. According to certain studies, the wet pulp efficacy of this kind of system ranges between 70 and 95 percent depending on air flow rate, weather conditions, application type, evaporative pad thickness, and some other factors. The direct ECS is classified into active and passive ECS. The active direct ECS are powered by electrical equipment. The passive direct ECS is a naturally driven system with little power usage.

Now, if you look at the types of ECS,. First is active ECS. Active direct ECS are powered by electrical systems to circulate air and water. This form of evaporative cooling system requires less electrical energy than typical vapor compression systems. Because of this, this form of evaporative cooling system is regarded as a less energy-demanding system with the potential for energy savings of even up to 90%.

Whereas the second type is the passive evaporative cooling system. The passive evaporative cooling system does not require energy to operate and relies on natural events. However, it is possible that a modest-capacity fan or pump will be required. This sort of system is climate-dependent. It is said that this sort of system may lower the interior air temperature by even up to 9 degrees Celsius.

Let us now look at the active direct evaporative cooling system. The active direct evaporative coolers are powered by electricity. But they only utilize a portion of that power to circulate air and water. Because of this, it is regarded as significantly less energy demanding than other traditional cooling systems. This system can save energy of up to 90%.

A basic direct evaporative cooler consists of an evaporative medium, which is a wettable and porous pad. It requires a fan that pushes air through the wetted medium. A water tank to collect the water that passes through the medium. A water tank. A water tank to collect the water from the medium.

A recirculation pump and a water distribution system. The direct evaporative cooling is an adiabatic cooling process, which means that the total enthalpy of the air remains constant throughout the operation. Water absorbs the sensible heat from the supply air and evaporates. This lowers the temperature and increases the humidity. So you can have pads that look like this, which are rigid pads or random pads, and then the outdoor air moves through the wetted pad.

So this is the wetted pad as shown here, and the air that comes out is moist cold air. And actually, water droplets pass through this pad, which is collected below. And it is called the active direct evaporative cooling system because there is use of a fan. Sometimes there could be use of a fan even to pull the outdoor air. So, the random media of the pad comprises of plastic fiber or foam supported by a plastic frame.

So, there can be a frame, and there can be the random media. This has low effectiveness, a short lifetime, and is difficult to clean. Whereas the rigid medium is blocks of corrugated materials like cellulose, plastic, and fiberglass. These have a longer lifetime and are cleaner. These can give effectiveness between 75 and 95 percent.

The remote pad is either random or rigid but is mounted on the wall or roof of a building. They have higher power consumption, and because it's difficult to clean and replace, they can get bacteria and mold growth, which is dangerous. Let us now look at the passive direct evaporative cooling system. In a passive direct evaporative cooling system, there is no need for the use of any electricity to either bring in air from outside or direct the cooled air inside. So, in order to cool the buildings without the need of mechanical equipment that uses electricity, passive cooling systems make use of natural energies, phenomena, and heat sinks.

Small fans and pumps could be needed, but they are not mandatory, and passive systems work even without that because these are climate-dependent. So, various approaches are used in hot and humid locations compared to hot and arid ones. With the use of these techniques, interior air temperature can be lowered by even up to 9 degrees Celsius. So, passive direct evaporative cooling systems are integrated systems primarily, and they come in the following types.

First is the Mashrabiya. So, this has been a common feature in Islamic construction. The Mashrabiya allows the structure to naturally cool and ventilate without using electricity. The wooden screens and windows offer shade, and they shield the building from the sun and let breezes help in cooling the building. So a Mashrabiya comprises an opening that allows breeze inside. So, the breeze comes inside.

It has a particular element that will direct the breeze towards the moisturizing element, and here the moisturizing element is a porous water pot. So a water pot, a clay pot, is kept filled with water, and it is porous. So the breeze flows through either the pot or over the pot. It flows over the pot and comes down. Now, this can happen in multiple phases depending on the way the pot is placed.

So, here a small variant is the use of a lattice screen here, like Jalis, and the breeze flows over the pot. There is a small element to collect water that could drip from the pot. So, this is a collector for dripping water. And there is a provision for the cool breeze to enter the room. So, there can be multiple, what should I say, there can be multiple ways in which this system can be used.

Effectively, the Mashrabiya looks like this from the outside, where you have the direct solar radiation; cool air is drawn inside through the grated jali or lattice screens, and what happens behind is actually this. There is an upper shading part for the mashrabiya. The upper section with balustrade is a wide mesh to provide sufficient air flow. The lower section with balusters on the closed mesh provides privacy and protects the direct sun. You have small windows that are openable.

And then there are cantilever brackets, and this whole element becomes an architectural feature of Islamic architecture, which is called the Mashrabaya. But actually it functions to cool the breeze inside through direct evaporative cooling in a passive manner. The next variant is a wind tower. So, this is a crucial component in Iran. So, Iranian traditional architecture has a wind tower, and settlements in hot, dry, and humid climates are home to it.

They resemble large chimneys when seen against the skyline of Iran's historic cities. They have vents on tops, as shown here. And these towers look like an Islamic element with varying designs. But actually, the vents in these slits are vents for breeze to go inside.

So when breeze enters inside. Then, at a lower level, there is some feature that is used to increase its humidity. So, these vent-topped vertical shafts direct the airflow into the inside to offer thermal comfort. So, this architectural feature shows how well architectural design blends with the surrounding landscape. So, as the air moves inside, there is some form for the water to humidify the air. It could be pots or it could be sprays, and then the air is diverted inside after it gets cooled.

So, this is how the wind tower works: you have the inlet, which diverts the air, and it is based on the direction of the wind. So, this comes, and then there are various ways of cooling the air, either with mist or making the earthen pots. The earthen pots filled with water are placed in the path of the breeze, which gets humidified and, in that process, cooled, and this is diverted into habitable space in a wind tower. Now, the principle is very simple. The principle behind evaporative cooling is that energy from the environment is absorbed During the phase transition from a liquid to a gas, all liquids can be turned into vapor with it but water vaporizes at a higher temperature, making it particularly effective.

Liquid water molecules are joined to one another by relatively strong hydrogen bonds. To separate them and convert the liquid into gas requires a huge amount of energy. Because when water vaporizes, it absorbs about 2257 kilojoules of energy. This is a very significant amount of cooling power. But the pace or rate at which it cools is dependent upon the air's relative humidity.

When air is dry, cooling works very well. This process still functions, but not as effectively in humid air. The other analogy or example of evaporative cooling is when sweat evaporates, allowing human perspiration to cool the body. Because perspiration is more efficient in dry heat, it is thus, in a sense, cooler. Due to water evaporation, the air near a river, lake, or ocean is frequently colder than the warm air around them.

Tree transpiration. This contributes to the coolness of a forest, and therefore when we move towards an area that has dense trees, we feel a little cool. The cold feeling we get after getting out of a shower because our skin is still wet is yet another example. Traditionally, people keep water in mud pots or earthen pots. That is another example. Let us look at the advantages of this system in terms of installation costs, running expenses, and electricity consumption.

This is a very inexpensive method. This is as compared to an air conditioner for cooling a home. It does not result in a power surge when turned on because there is no compressor. There is no need for special refrigerants here, and refrigerants sometimes are a big reason for global warming. It raises humidity, which may make people and animals more comfortable and reduce the static electricity in arid settings. By acting as a filter, the water-soaked pad clears the air of dust, pollen, and other allergens and acts as a filter.

This system still has some disadvantages. Air conditioners are able to reduce air temperature more than evaporative coolers do. This system further raises the relative humidity. This keeps sweat from draining in an already humid atmosphere, and it can speed up corrosion. This can encourage surface and water condensation. Wooden doors and furniture can become expanded and swollen.

Also, too much moisture can encourage the growth of mold, mildew, and algae. It needs water on hand all the time. Mineral deposits left by hard water demand regular pad replacement and plumbing upkeep. The commercial units with dry pads provide a small disadvantage of being fire-prone. Mosquitoes can become a huge nuisance if the home has a cooler that is not properly maintained.

When there is adequate air circulation that drives humid air out of the space, evaporative cooling operates. An energy-efficient home's efficiency is sometimes greatly reduced when a swamp cooler is added because of the requirement of a chimney or a vent. The biggest disadvantage of this system can be that unless it is well maintained, the impact of the growth of mildew, mold, and fungus can have a very negative impact on people's health. And these are too small to be seen by the naked eye. So regular cleaning and maintenance is a must if this technique is to be used in any form.

Because here we are talking only of the principle. How you translate it architecturally is entirely up to you. Let us see the applications of this technique and also a few case studies. The master plan for California State University, St. Bernardino has the evaporative cooling system, and you can see how this system is integrated with the landscape element in the form of a water pool. So, there is a long tower through which breeze is directed inside.

There are micronizers, but then that drips and falls and gets connected to a water body below. The breeze flows out. You can notice here, but we will be looking at it in greater detail later, that there are these tubes that are called radiant floor cooling, which we will be looking at as an advanced passive technique in another class. The clay pot evaporative cooling is yet another system where there is a temperature drop of approximately 6 degrees Celsius. So, the temperature drops from 42 degrees Celsius to 36 degrees Celsius by use of the clay pot evaporative cooling system.

The School of Planning and Architecture at Bhopal, designed by Abhin Studio, has also tried to incorporate the passive downdraft evaporative cooling system because of which the air is supposedly because Bhopal can have a very warm climate too. the air from outside is brought in and then there is a staircase or circulation terraces which act as thermal buffers and there is provision for the breeze to enter the building and it gets now camouflaged as a design element because of the contemporary style or contemporary translation of this technique. So, in today's class, a very simple technique is direct evaporative cooling. We also saw the various forms in which this concept can get translated in architecture to cool indoor air. This technique is primarily suitable for hot and dry climates and is not really suitable for humid climates.

That is because this system involves the use of a water body in order to cool the air. In order to make the dry air humid and, in that process, cool the air. air that is already humid will not function effectively using this technique. How this technique gets translated in architecture is left to the individual designer. With this, we will stop today's class where we have studied about direct evaporative cooling and its translation in architecture, vernacular as well as in the contemporary context.

So, we will meet in the next class with yet another topic on advanced passive systems. Thank you.