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

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Lecture 02

Wind towers

Hello all. So, we have been seeing a series of advanced passive strategies, and as one among them, today we will see another advanced passive strategy, and that is the wind tower. It is a very interesting strategy because there is nothing new about this strategy. So, these are called wind towers or even wind catchers. So, they are called by different names. Now, windcatcher is a traditional element that has been used as a passive cooling technique in hot, dry regions for many centuries.

They are known by several names, such as wind catcher and wind scoop. They are called Malkaf or Badgir, which is actually a wind tower, and it is a cooling architectural feature. They are called Batting in Syria. Even Egyptians call it the Malkaf.

It is called Badger or Boudgir in Iran, Iraq, and Pakistan. It's called Kasteel in Bahrain. It's called Badkir in Qatar. So, wind catchers have been used for centuries and they have had different names. So, wind catchers are attributed to the Persians by some historians and archaeologists.

While others think the first examples were constructed in the North African deserts, especially in Egypt. Now wind catchers are a natural solution for climatic problems in hot and dry climates, and they are used in North Africa, West Asia, as well as in India. So it's an architectural feature and a spatial device constructed on the roof to extract fresh air into the rooms and the interior corridors of the building. It provides passive cooling and is also a source of natural ventilation for the building. Tall towers, wind catchers, rooftop vents—these catch the wind cooling the interior spaces.

If we look at the function of the wind catcher, there are two functions. The first function is to catch the prevailing wind and direct the wind into the interior spaces of the buildings. The next function is to extract and remove the stale air or the polluted air outside. Thus, it helps in supplying fresh air and generating clean ventilation. The working principle of the wind tower is that it works on the principles of natural pressure and temperature differentials.

Air movement is created by the rising of warm air and the lowering of cool air. As we have already seen, warm air is light; it rises up, and cool air is heavy and tends to settle down. As the air above the land gets warmer, it rises and creates an area of low pressure because, in a way, it forms a vacuum. You know, it's not exactly a vacuum, but then when the air rises, there is a low pressure formed. When air continues to rise, it moves towards water surfaces where it falls and creates an area of high pressure and pushes cold air towards the land.

This movement is what creates the wind, and this is the basic or very underlying concept of a wind tower. The padgir, or windcatcher, functions by trapping the faster-moving air above the dense settlements of the region. It exploits pressure differentials existing between the vents above roof level and room outlet level. These towers work by directing the cool air that is circulating at higher levels with high density. This is pulled down, and this air enters the interior space with higher pressure.

Once the cool air enters the space, the warm air circulating inside the interior space is pushed out through openings created on the opposite side. So, if we look at the rise and evolution of wind tower design, the pharaonic era, which is the era of the pharaohs,. Pharaohs were the Egyptian kings. So, they had a variant of windcatcher that would look like these so these were, in a sense, wind catchers then during the medieval and ottoman eras, knowingly or unknowingly During the medieval and Ottoman eras, there was a very conscious decision to create structures which would bring air and create structures as outlets because warm air would rise up. Then this has also been demonstrated in the mosque of Al Salil Talai.

This is in 1160 AD, and you can see a small vent here that initiates and generates wind movement inside. The Christian hermitages in the desert of Esna show that there is air flow in the hermitage in the desert of Esna. Through these- they were not towers, but definitely there were channels used to direct and trap the breeze with outlets. The Khanqah and Mausoleum of Sultan Baybars also had consciously designed towers to suck in the outside air. So, these were all variants, initial variants of the windcatcher.

The Khalifa Stadium in Doha, Qatar, has very consciously designed a wind tower. Now, conventional and traditional wind towers were of different types. The first is a one-sided wind tower. The second is a two-sided wind tower. So, a one-sided wind tower had inlets only on one side.

Whereas, a two-sided wind tower had openings on both the sides. On this side as well as on this side. The 4, 6, 8 sided wind towers had multiple openings on all the directions and it used to be tower over tower and then there is the cylindrical wind tower which is actually in the form of cylinders and has inlets on all its sides. Now wind towers also have certain limitations. The badkir has an opening with no protection which means if it rains then there is a potential for precipitation or water to enter inside.

But wind towers are most effective in hot and dry condition and precipitation there is pretty much low. But it still provides a vent for insects to enter inside. The cooling potential of wind catchers is limited. So there is only that much a windcatcher can work because the outside air itself is warm. Then four-sided badkir on the roof.

It has the fresh, cool air drawn from the building by one of the sides. It gets mixed by the warm air being drawn out by the other three sides. During the winter, the traditional badgir stills allow cold air into the building and shift the warm air out. They do not have any applications in regions that have very low wind speeds. So, the wind speed has to be high.

If the wind speed is low, then the badgir or the wind tower does not have any function or any effectiveness. Let us look at the working principle of the badgir. So, a badgir's ability to function is influenced by the temperature and wind speed of the day. A badgir can operate in four primary modes, switching between intake and outflow functions. When there is no breeze at night and the Badgir's temperature is greater than the ambient temperature, then through the apertures in the tower, the Badgir draws air upwards and forth just like a chimney.

The walls of the Badgir, especially the interior walls dividing the air passages, collect heat throughout the day and then release it into the colder air within the surrounding the Badgir tower. Warmer air has less density, which lowers the air pressure at the top of the tower and produces an upward draft. Cool ambient air is brought into the building through the doors and windows from the courtyard as a result of the tower drawing up the air inside the structure. The night air When that air descends, the badgir cools the chambers as the air is forced down it. Here, the cooling can still be successful enough to bring the building's temperature close to that of the outside air even when the tower walls warm the night air before it reaches the structure.

When there is no breeze during the day, what happens? When there is no breeze during the day and the badgir's temperature is lower than the ambient air temperature, the badgir functions similarly to how a chimney does. The outside air is hot, and the hot outside air hits the Badgir's walls, which have been chilled due to the air from the previous night. Because the night sky is a big sink of cool air. It flows down the badgir and gets thicker and colder. When I say thicker, I mean it becomes denser and cooler.

The badgir walls warm up as a result of absorbing heat from the surrounding air. The air flow down through the tower and into the building stops when the temperature of the badgir reaches or surpasses that of the surrounding air and the tower starts to function more like a chimney. The fourth condition is when there is wind during the day. When wind blows into the badgir's vents, it is driven through it and cools down because it comes into contact with the walls. Now, let us look at the elements of the windcatcher.

The roof, the shelf, the stock, the blade, and the chimney are the components that make up a wind catcher. What is the roof? Now roofs can offer in several forms. Three types of roof wind catchers are available. One is flat, another is slanted, and the third is curved.

Second is shelf. The shelf that houses the blades and the air-passing channel in the windcatcher head is called the shelf. stalk. So, the stock of the windcatcher is the portion that sits between the shelf and the chamber. The taller the windcatcher, the taller is the stock. Then the fourth element is the blades.

So, blades are the components where brick and mud brick, which split the shelf into smaller ducts, happen. Let us look at the factors affecting the efficiency of a windcatcher. Now first is the height. Height becomes very important. So wind speed and wind catcher height are directly correlated.

More the height better is the working of the windcatcher. Second is the windcatcher's cross section. The shaft size and the volume of air admitted into the building are directly correlated. So, the bigger the shaft size, the more volume that it can accommodate. More volume of air can be accommodated for movement.

Third are the intake and exhaust openings because these impact velocity. The outlet entrance is close to the ground, while the entry aperture faces the direction of the wind. So you need a minimal quantity of apertures for outlets. So, the wind direction and the long axis of the windcatcher entry must be aligned with each other. Air speed decreases with a larger number of openings, and air speed increases when a minimum number of openings are provided at the outlet.

So, here the speed is decreased, whereas here the air is capable of gushing out when the opening size is small. Let us quickly look at the case study of the Torrent Research Center in Ahmedabad, which has used a number of wind catchers in their designs. So, the Torrent Research Centre is in Gujarat, India, and it is a complex of research laboratories with supporting facilities and infrastructure. It is located on the outskirts of Ahmedabad. This building uses passive downdraft evaporative cooling for large-scale office buildings and demonstrates that it is possible to achieve human comfort in dry, hot regions.

So, in the plan, you can see the wind captures here in section and also this entire system in the center; they operate together. So, you can see this functions as the inlet, the center one Here in the windcatcher, they have placed water for increasing the humidity and it functions like a passive downdraft evaporative cooler. But during certain months the sprinklers are not operated to enable air flow into the building of appropriate temperature through the baffles, and the outlet air is taken out through the exterior chimney or the exterior wind catcher. So, as we had already seen during the cool season, the strategy that they use is different from that of the warm season and from that of the monsoon season. So, based on the season, the outlets are closed, the inlets are closed, or the sprinklers do not function.

When sprinklers do not function, they operate more like a windcatcher. Let us look at the second case study, and that is the classroom building located in Erbil, Iraq. In this study, an IESV sustainable tool as well as CFD is used to examine the efficiency of the passive system in three-floor classrooms in a hot, arid climate, which is Erbil. Now, if we look at the physical attributes of the base case model, glazing is assumed to be clear and single glazing and covers a 14 percent window-to-wall ratio. The construction of the walls of a single uninsulated leaf wall with a concrete block is used.

the glasses have a dimension of 8 meters by 5 meters by 4 meters and you can see that here in And here you can see in the proposed case the study is done to understand what happens when the tower height is 3 meters, what happens when it is 6 meters and what happens when it is 9 meters for the base case for which the plan is shown here. The IESVE model of the three alternatives with the heights of 3 meters, 6 meters, and 9 meters is considered. So, wind catcher is more effective during the early morning than in the late afternoon, with a 3-degree difference in temperature between these two periods. The findings showed that increasing the height leads to enhanced wind capture performance in terms of bringing down the mean radiant temperature and also by increasing the number of hours within the thermal comfort zone. The tower, which had a 6 meter height, gave the best results because it raised the percentage of hours within the comfort zone to more than 75% of the total hours.

In the study, it was found that the wind catcher is more effective in the early morning than in the late afternoon. With a 3-degree difference in the temperature between morning and late afternoon. Increasing the wind capture height is better to enhance its performance. Because by doing so, it reduces the mean radiant temperature.

And also increases the thermal comfort hours. 6 meters of height seem to give the best results. The windcatcher also has an impact on bringing down the energy demand of the cooling system. Raising the height of the windcatcher will lead to better performance, but it is not supposedly shown in this study. When the outdoor temperature is maximized to say 31.5 degrees centigrade, at about 1.30 pm, the windcatcher room temperature is shown to be 27.5 degrees centigrade in model 1, and it shows about 28 degrees centigrade in model 2, and it shows 28.5 degrees centigrade in model 3. Hence, these kind of wind catchers can decrease the temperature between 3 and 5 degree Celsius when the outdoor temperature is at its peak So, outdoor temperature decreases gradually in the afternoon, but indoor air temperature also declines anywhere between 3 degrees to 5 degrees centigrade up to 4 pm time. The best performance seemed to be by the model 2, as the number of hours that the MRT mean radiant temperature was within the comfort zone for nearly 65 percent as compared to 60 percent for model 1 and 50 percent for model 3.

So, you can see the mean radiant temperature of the second one, model 2, performed better up to 1 o'clock, but after 1 o'clock it was model 1, which performed better or similar to model 2 until midnight. So, between midnight and 1 pm, model 2 worked better, whereas between 1 pm and midnight, it was model 1, which was equal to or better performing than model 2. And there was a difference of approximately 3 degrees centigrade to 5 degrees centigrade between the outside mean radiant temperature and the indoor mean radiant temperature. Let us now look at the application of wind catchers in the contemporary context. So, wind catchers utilize wind and renewable energy to improve the quality of indoor air and also increase the thermal performance in buildings.

So, these uses can be found in Pakistan as well as in India. Using certain roof elements to increase the ventilation of buildings is a concept that we have derived from vernacular architecture of the Middle East, and contemporary architects have also tried to adapt this in their modern buildings. This they do in order to take advantage of the traditional wind catchers and eliminate their limits to adopt them with improved building types and technologies. Many modern and commercial wind catchers have been used. Today we will see the example of the University of Qatar in Doha.

This was built in the years 1985 to 1991. where in the design itself they have integrated with a new type of a very simple windcatcher with many openings on each side. Another different example is the French school named Lysi Chasti Galle in Damascus, Syria, with a design to revive the use of local materials and also bring in passive design strategies for natural ventilation. When it comes to the University of Doha, at the University of Doha, each chimney works independently as a thermal regulator to regulate the interior space. The vents are oriented towards predominant cool air, and they are staggered to avoid the blocking of these currents. The inside of each of these towers is divided into two parts to let in the warm air and also the cold currents to flow without mixing each other.

First, the lower-temperature air or the cold air passes through the opening of the vent; it hits the interior wall because of the stack effect Cool air with more density descends down because it is heavier; it comes down to the lower levels of the building and cools the interior space Once this air cools the interior space, it means it becomes warm at the inhabitant level. So, it ascends again to double-height space and leaves through small openings, which are located on the other side of the chimney. So this simple passive and inexpensive process to bring down the air temperature at human body level makes the person stay cool throughout the day. There have been several interpretations of the wind tower in the contemporary context because wind towers, though they are an advanced passive technology, we use another specific attachment to the building.

We call it an advanced passive technique. But traditionally, wind catchers have been used in vernacular architecture all over the world, especially in hot and dry climates. It is an inexpensive method and an effective method that has been proven over centuries. So, we stop our class with having discussed the wind catcher, and we will continue to discuss another advanced passive technique in the next class.