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

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

Week: 02

Lecture 01

Advanced Passive Strategies - Passive Heating Strategies

Hello everyone, until our last class, we have seen simple passive strategies, we have listed the strategies, we have seen its principles, we have seen its application, we have seen how it can get translated into architecture. Today we will be looking at advanced passive strategies. So today I will give you an introduction to advanced passive strategies. How do advanced passive strategies fall into the realm of passive techniques? So, you can see that under passive techniques, which we had already seen, we have advanced passive techniques under which we have passive cooling and passive heating. Passive cooling comprises natural night ventilation, earth-to-air heat exchanges, evaporative cooling, passive downdraft evaporative cooling, radiant cooling, a green roof, a wind tower, a double-skin facade, and a double roof. Under passive heating, we have trombe wall, solarium, water wall, phase change materials, earth air exchanger, thermal siphoning, and earth air tunnels.

Now, the components required for advanced passive systems. This is important. You need to have definitely a collector. A collector would be a contraption, a building part, or an element that will collect the heat.

You need to have an absorber. After collecting, the heat has to be absorbed by some particular contraption. This heat must be stored. You should have a facility to distribute the heat and to control the distribution. So, these are definitely the five things.

Now, let us look at an example. Okay, with an example, let us look at what all are each of these elements. Now first is the collector. Now, from where does the heat enter the building? The heat enters the building through the aperture. So this becomes the collector.

The heat that comes in needs an absorber. Which is the absorber? The absorber is the floor, the walls. The roof; these are all absorbers. Then where does it get stored? In the flooring, wall, and roofing based on the thermal mass, which we already saw. Then the distributor.

The air moves inside, and that becomes the distributor. Sometimes even this material because of radiation can be called a distributor. Control comes in the form of shading devices. So, the shading devices will act like a control. So, passive cooling systems differ from mechanical systems in that they rely only on natural heat sinks to remove heat from a building.

They derive cooling directly from evaporation, convection, and radiation without the use of any intermediate electrical devices or drivers. So, passive cooling systems do not use any mechanical systems. When it comes to ventilation, ventilation is typically thought about during the day when it is hot. So, a passive low-energy method for increasing the effectiveness of ventilation uses fans to flush heat from a building during the night. Such nocturnal cooling reduces indoor air and surface temperatures essentially pre-cooling the building for the next day.

So, nocturnal radiant cooling or roof cooling—this technique can be used. So, the coldest environmental heat sink available is the night sky. This important resource for passive cooling systems is as much as 30 degrees Fahrenheit below ambient air. All roofs radiate heat into the night sky because the night sky is cool. So, the building uses the night sky as a heat sink.

The effectiveness of nocturnal radiant cooling is increased by combining this with evaporative roof cooling during the day and, to a limited extent, through the night hours. How can this be done during day? During the day, you can spray the roof with some water, and this begins to radiate interior building heat to the atmosphere much earlier in the evening than an uncooled roof. This technique has been typically used by our forefathers. If you remember, at around 4 o'clock or 5 o'clock, our grandmothers or mothers would go, and they would throw water on the roof every evening. What happens because of this? So by 8 p.

m. the room starts getting cooler when you do this, because it releases more energy to provide significantly cooler temperatures in the building during the day as well as night. What are the benefits of advanced passive strategies over simple passive strategies? Now the benefits of advanced passive strategies over simple passive strategies will include expanded heating, cooling storage capacity, advanced heat modulation, and control. It's more competent and efficient. Mechanical means or a combination can be introduced if the heating or cooling load is greater than what can be balanced by advanced passive techniques. Combining with mechanical means increases efficiency.

These buildings are energy efficient. Therefore, they are also economic. They have better indoor air quality. They have better physiological comfort and reduced dependency on electric grid. They are more energy efficient because a passive house is an extremely energy efficient home in which a comfortable interior climate can be maintained without active heating and cooling systems.

They are also economic because passive house design eliminates the need for traditional heating systems in even the most difficult of climates. So the cost of heating the room through oil or gas can be reduced. The passive house concept uses controlled mechanical ventilation. This continuously replaces stale, stagnant, humid, or moist air, which can cause sick building syndrome, and this air gets replaced with fresh outdoor air. While the windows in passive homes can be opened just like windows in any other house, most people tend to keep them closed.

So bringing in fresh air becomes very difficult. So you need filtered ventilation systems. Passive house design strives to maintain a comfortable, even equal temperature throughout the home with low temperature variations compared to a house that is not designed with passive features. The low energy consumption required by a passive house makes it easy to supply some or the entire household electricity through clean on-site power sources like wind energy, solar energy, etc. What are the other benefits of advanced passive cooling systems? Now, passive cooling is becoming more important with climate change.

Climate change will see our average temperature increase, and extreme events will also increase. What are extreme events in the context of cooling buildings? Heat waves. We already see heat waves occurring more often, more frequently for longer durations. With careful design for passive cooling, we can keep the home more comfortable and cool with reduced energy costs. So cooling buildings is about reducing the heat gain.

For example, by installing insulation and shading windows, walls, and roofs. Increasing heat loss and access to cooling sources for example, by using earth coupling or encouraging air movement can also increase physiological comfort physiological comfort that affects our perception of comfort, that is psychological comfort so it can increase our physiological comfort These are the physical factors necessary for comfort, such as bringing in a breeze. When someone is perspiring and breeze flows over, it brings physiological comfort. It can also increase psychological comfort through our perception. For example, acclimatization levels and air movement.

So, it causes psychological comfort. Now, how does this work? So, passive heating relies on trapping the sun. Here you can see in order to trap a sun the solar radiation here you can see in order to have passive heating. The glazing is oriented towards the solar direction. So, it traps the heat in a sun space. This wall acts as a storage space for heat.

The heat is stored in this wall, and this gets released to the indoors. This is how passive heating can happen. While passive cooling relies on cooling the building by using the environment as a natural sink. Here is an example where this is called an earth-air tunnel. This is a combination of many passive techniques.

One of this is an earth-air tunnel. So, this is an earth-air tunnel where you have a wind catcher that catches the wind and flows through a pipe that is buried underground. In this process, the hot air becomes cool air, and this gets siphoned inside the building. The inlet is at a lower level; therefore, warm air, which is lighter, tends to rise and escape. These techniques (in detail) I will be handling in the next few classes, not immediately next but in the forthcoming classes.

Now, passive heating strategies—I will quickly give you a glimpse of how some of the passive strategies happen and then the details we will anyway see in the next few classes. Trombe wall. So, these walls are built of a dark colored material—very heavy material, sometimes concrete—that is built facing the sun so that the solar radiation is incident on the wall. The wall absorbs and stores the heat coming from the direct solar radiation. Cool air from the building enters the air channel between the wall and the glazing through a vent.

This is present at the bottom of the wall also. At night, the trombe wall functions differently. The vents at the top and bottom of the wall are closed to ensure that the trapped heat remains inside. When the outside is very cold, the inside remains warm because this heat from the wall is radiated as well as heat from the sunspace or the small air space has flown in during the day.

Next we will see sun space. This is also used in the cold climate. The main principle is that this acts on the principle of direct radiation. The total direct solar radiation available for the sun space is deeply connected to the location of the sun space, the prevailing climate condition of that place, and the orientation of the window area. The effect of the glazing is that the glazing is responsible for the solar gains and the heat losses. transmittance happens, which is the radiation that is neither reflected nor absorbed and is called transmitted.

Translucency and transparency of the material are another important factor. Translucent material creates diffusion, which means radiation that enters the space is scattered and distributed evenly in all the sunspace surfaces, avoiding areas of overheating. Some of it also gets reflected and absorbed. So, these two main parameters can affect the reflectance and absorption, and that has to do with the material and the angle of incidence. Multiple glazing could also be used, and the use of more than one layer helps in reducing the heat losses as the gap between the layers is usually air.

It acts like insulation, but the transmittance is connected to the absorptance and the reflectance of the glazing. By raising the glazing layers, the transmittance gets lowered. Thus, even if the heat losses reduce at the same time, the heat gains are also negatively affected. Orientation must be proper. So, in order to achieve optimization and design, the glazing has to be perpendicular to the radiation received at any time.

Heat storage: the first phase of the heat storage procedure is the solar radiation absorption. The surface color and texture are the two main parameters that affect the absorption. Dark-colored surfaces are generally higher in absorption than compared to light colors. The heat storage medium should be very effective, and this is higher when the direct radiation strikes the surface. So, the sunspace floor or the north or the common wall with the adjoining room are at preferable locations for the heat storage to take place.

Heat capacity of the materials is very important. It is the physical property that is defined by the amount of heat needed in order for a mass to change its temperature by one unit. Thermal conductivity. In order for the heat to get stored in a body, it needs to be transferred from the outside surface through its body. Heat always flows from a hotter to a colder body.

The masonry that is used, the masonry used, and the sunspace for heat storage need to have both high heat capacity and thermal conductivity, like say, brick or concrete, or stone. Water containers: the heat capacity of the water is higher than the materials used in masonry, so they can absorb and utilize higher amounts of solar heat. Heat conservation is an important thing. The most common are heat losses through the glazing, the infiltration, the exfiltration, and the conduction heat losses through its opaque surfaces like the walls, the roofs, and the ceiling.

Then you have convection losses. Convection heat losses occur mainly due to the contact of the warm air that flows in the sunspace with the cool interior surface of the glazing. Radiation heat losses: Radiation heat losses, especially through the glazing, are a significant contributor to the general sunspace heat losses. Then you have losses through glazing: The most common measure to increase heat flow resistance through the glazing is the use of double glazing that is separated by a thin layer of air. The air layer functions as insulation.

Then you have opaque surface insulation. It is preferable to use insulative material in the common wall so the heat flow to the interior is not embedded. The addition of insulation to the other opaque surfaces of the sunspace, such as walls, ceiling and floor can help to reduce the conduction heat losses. Then you could have movable insulation. The insulation can be placed on glass during the nighttime outside or inside the sunspace glazing in order to prevent the heat flow to the exterior and therefore capitalize on a higher amount of the stored heat produced during day time. So, in this slide or with this slide, we have seen some very important and crucial keywords.

Those words are heat, storage medium, and I have applied all these terminologies to one advanced passive design, which is a sunspace. Then heat capacity of the material, which is a physical property. Thermal conductivity, heat conservation, convection losses, radiation heat loss, insulation of opaque surfaces, So, we have covered so many definitions with respect to sunspace. Since these are definitions, they are applicable to sunspace and also to the other concepts of advanced passive techniques.

The second one is thermosiphons. A thermosiphon is a method of passive heat exchange based on natural convection. It circulates a liquid or vapor without the need for a mechanical pump or other moving parts. Apart from passive heating, thermosiphons can also be used for circulation of liquids and volatile gases in heating and cooling applications such as heat pump, water heaters, boilers, etc. The most famous type of solar water heater used worldwide works on this principle. A thermosyphon solar heat collector works on the principle that hot air is lighter and rises up while the heavier cool air settles down and is sucked back into the thermosiphon system.

The third advanced passive technique is a solar chimney. So a solar chimney is used in a similar climate but to improve the stack ventilation. These structures have openings at the ends made up of some heat-absorbing material to increase the temperature and speed up the stack effect. Then we have wind towers, which can be used in hot and dry as well as warm and humid climates. In a wind tower, the hot air enters the tower through the openings of the tower, gets cooled, and this heavier air sinks down. Because it gets cooled and after a whole day of air exchanges, the tower becomes warm in the evening.

During the night, as we already saw, the outside nocturnal sky is a great heat sink. So the cooler ambient air comes in contact with the bottom of the tower through the rooms. The lower wall absorbs heat during the daytime and releases it at night, warming the cool night air in the tower. Another strategy that we will see is passive drown draft cooling.

This is used in hot and dry climates. In this system, wind catchers guide outside air over water-filled pots. There can be pots here or micronizers that throw the mist, and then the air that comes in gets moist and it settles down. So, now these wind catchers come as the primary rudiments of an architectural form as well. We will not go too deep into this now because we will look at it later in greater depth.

Then you have the earth-air tunnel. So this is used in hot and dry as well as warm and humid climates. Using the passive cooling effect of ground, the device can lower the air temperature in the air duct by even up to 10.8 degrees centigrade. Due to the rocky terrain of the site location, this technique cannot be used everywhere.

When the terrain is good enough, this technique can be used. Then you have earth-air contact. So, this works on the principle that the soil temperature at a depth of about 12 feet or more stays fairly constant throughout the year and it is approximately equal to the average annual ambient air temperature. The ground can therefore be used as a heat sink for cooling in summer and heating in the winter. For example, for Bangalore, the temperature below 12 feet is about 24 degrees Celsius, and it is constant throughout the year. In Delhi, the earth's temperature at a depth of 12 feet is nearly constant at 23 degrees Celsius throughout the year.

There are two strategies of earth-air contact. One is the direct earth contact. So, in this direct earth contact, the building is actually buried inside the earth or it is bermed inside the earth, because of which there is greater contact between the earth and the building. When it can be done either partially or completely, as shown in this picture. Here it is done partially.

Here almost the entire building is buried. So, the advantages are that it has limited infiltration and heat losses, it has solar and heat protection, it has reduction of noise and vibration, fire and storm protection, and improved safety. Its disadvantages include condensation, slow response to changing conditions, poor daylight, and sometimes poor indoor air quality. When we look at these in greater depth, we will analyze their advantages and disadvantages further. So, in this class, I have given you a glimpse of what are advanced passive strategies and what these strategies are actually in a small glimpse.

We will continue with this topic in the forthcoming class. Until then, see you all. Thank you.