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

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Week: 09

Lecture 04

Sunspace

Hello everyone. So, we have been seeing a series of advanced passive strategies, and today we will have a look at another advanced passive strategy, which is the son's case. Now sunspace is a very popular passive solar technique, and this is used to collect energy from the sun. A sunspace is normally south-facing. It is a glazed area that is located mostly outside of the main fabric envelope of the building. This space naturally heats and cools, allowing daytime temperatures to rise more and nighttime temperatures to fall further than the comfort zone temperature of the adjoining living space.

So, this enables the indoor to maintain a temperature that feels comfortable through day and night. The climatic conditions in which sunspaces are used are primarily cold climates and temperate climates. In the cold climate, the temperature could drop down to 6.7 and further down even to 1 degree Celsius.

In the temperate climate also, the temperature could fall somewhere between 7.2 degrees and 10 degrees. So, attached sunspaces, also called conservatories, work much like a vented trombe wall. They can heat spaces both through radiation as well as convection. The difference is that the space between the glass and the thermal mass creates a habitable space.

So, in other kinds of heating spaces, the place where the heating actually happens is usually not habitable, but in sunspaces these become habitable or usable space. So, the main principle of south-facing sunspaces and conservatories is similar to a trombe wall but with a large and therefore functional cavity. This cavity becomes functional because the space is large. Glass allows solar radiation to fall onto this space. So, the solar beam penetrates through the external glazing provided here, and it traps and keeps the heat inside.

Part of the heat is stored in the thermal storage medium, which is the wall and the floor. This will be redistributed back to the space at a later date, which is at night, and part of the heat can be directly carried into the space through convection, and the convection currents start. So the air convection through the vent opening at the wall when heating is needed immediately can be opened, and it starts the convection process. At night, what happens? At night, the night sky acts like a cooling sink, and heat starts to get radiated outside because the indoor is warm and the outside is cool. Heat from the storage medium, which is the wall and the floor, also radiates out, causing a convection current inside.

Of course, there is radiation of heat between the inside and the outside through the walls too. The uncomplicated approach for absorbing solar energy in the building is the use of greenhouse effect and greenhouse optimization. In the greenhouse, when I say greenhouse, I do not mean greenhouse gases; I mean the actual conservatory greenhouse. It traps the radiation from the sun without any other element with only a translucent or transparent medium, and it makes it a very important system in cold climates. For utilizing the sun's energy as passive heating, it becomes very important for us to store the energy, distribute the energy, and conserve the heat, and in that scenario, the sunspace becomes very important.

So, it is a very interesting architectural find in the energy attitude of solar radiation usage, which gives energy benefits in terms of bringing down the demand for winter energy. Sunspaces are designed to collect energy. solar energy. So, the energy is collected, how? In floors and the walls. So, the collection happens through the glass and is stored in the floor and the walls.

So, you know the solar energy is how much of solar energy is collected depends on the quality of the system and also the weather conditions. So, glass allows the solar radiation to penetrate through the glazing, and it keeps the heat inside. A small part of the heat is stored in the thermal storage, which is nothing but the wall and the floor, and this gets redistributed back to the space at night. So sunspaces are primarily designed to collect the sun's energy and reduce the dependence on other forms of energy. So, the solar radiation gets transmitted through the glazed shell, and this is absorbed by the opaque and glazed walls, and some of it is absorbed by the surrounding environment of the solar space.

Eventually, this energy, which is in the form of heat, is again transmitted to reach the adjacent spaces. Sunspaces are usually used for buildings for heating in winter and cold seasons, taking into account reducing the load on the energy system to increase the heating. In the process of the sunspace design as a passive technology in buildings, its application in the summer season is not really considered seeing that overheating defects in the hot time happen, and consequently the advantage of this passive system is not really utilized during the summer time. In general, the operation of the solar sunspace is with the help of solar energy, the glazing, which is actually the collector, solar energy is the source, glazing is the collector, heat storage, which is in the form of floor and walls, is the storage system.

And then the dispersion happens by means of natural phenomena like conduction and convection.

It allows for heat conservation and gives us some scope for controlling the way heat must flow back indoors. Now let us look at the operation of the sunspace. The solar energy is first the direct source of energy and gives us direct radiation. The total direct solar radiation available for a sunspace is related to the location of the sunspace, the prevailing climate conditions of the area, and the orientation of the window area. If we look at the effect of glazing, the glazing is responsible for solar gain as well as heat losses.

Transmittance: the radiation that is neither reflected nor absorbed is transmitted. Translucent materials create diffusion. Which means radiation that enters the solar space gets scattered and distributed evenly in the entire solar space, avoiding areas of overheating. Then absorption. So two main parameters that can affect the reflectance and absorption are the material and the angle of incidence.

Then multiple glazing. The use of more than one layer helps in reducing heat losses as the gap between layers acts like insulation. So, having two layers of glass with a gap in between prevents heat loss. However, since the transmittance is connected to the absorptance and the reflectance of the glazing, by increasing the glazing layer, the transmittance also gets lower. Thus, even if the heat loss reduces, at the same time, heat gain also gets adversely affected.

And then the last is orientation. In order to achieve optimization and design, the glazing has to be perpendicular to the radiation received at any time, but that is not always possible. So, if we look at the factors that affect the functioning of sunspace, First is solar energy, the intensity of solar energy that is got. Second is the transmittance of glazing. So, first is solar energy, its intensity.

Second is the transmittance of the glass. Third is whether it is translucent or transparent. Fourth are its reflection and absorption properties. Fifth is the use of multiple glazing, and sixth is the orientation of the glass with respect to solar radiation. So, these are the parameters that affect the solar radiation that can be tapped and captured.

Then the next parameter is the heat storage. So, the first phase of the heat storage procedure is the solar radiation absorption. The surface color and the texture are the two main parameters that affect the absorption. Dark-colored surfaces in general absorb a higher portion of solar radiation than light-colored surfaces. The second is heat storage mediums.

The effectiveness of heat storage is higher when the direct solar radiation strikes a surface.

So, the sunspace floor or the common wall with the adjoining room are the preferable locations for heat storage to happen. Third is the heat capacity of materials. Now, heat capacity is a physical property of the masonry, and it is defined by the amount of heat needed in order for a mass to change its temperature by one unit. Fourth is the thermal conductivity.

Again, that is a physical property of the material. In order to enable the heat to get stored in the material, it needs to be transferred from the outside surface through its body, and this heat flow is always from hotter to colder body. Fifth is the masonry. The masonry used in a sunspace for heat storage needs to have high heat capacity as well as thermal conductivity. So, good materials that have both high heat capacity and thermal conductivity are normally considered to be brick, concrete, and stone.

So, we have already seen thermal mass as a concept, and that is what you need to understand: that the thermal mass must be high of the flooring material as well as the walling material. The heat capacity of water is higher than the materials used in masonry. So, they can absorb and utilize higher amounts of solar heat. And this is the concept that is also used in the water wall. I am just trying to connect both of them.

Then next is heat conservation. Now, the most common are heat losses through the glazing, the infiltration, the exfiltration, and the conduction heat losses through its opaque surfaces like the floor, the wall, and the ceiling. So, first are convection losses. So, convection heat losses occur mainly due to the contact of warm air that flows in the sunspace with the cool interior surface of the glazing. Then radiation heat loss also happens. So, radiation heat losses, especially through the glazing, are a significant contributor to the general sunspace heat losses.

third is losses through glazing. So, 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, and this air functions as insulation. Fourth is opaque surface insulation. Now, it is preferable to use no insulative layers in common walls so that the heat flow to the interior is not impeded. The addition of insulation to the other opaque walls of the sunspace, such as the wall, ceiling, and floor, can help to reduce the conduction heat losses.

Fifth is 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 the higher amount of heat storage produced during the daytime. So, if there is some insulation provided only at night, then this heat loss can be reduced. So, far we have seen what should be the properties of the glazing; we have seen what should be the properties of the wall, and here we are seeing the factors that are responsible for the transmittance of heat. Next, we will see heat distribution. So, the role of thermal mass in sunspace is to store the heat that is distributed to various rooms during diurnal periods without sunlight or during the night.

The materials that are used must have a thermal mass that needs to have very high volumetric heat capacity. Normally we saw that materials for heat storage should be something like concrete, brick, water, etc. Compressed earth blocks also function very well. So, these moving elements within the sunspace or other rooms such as water tanks can also serve as good thermal mass because you can remove the thermal mass and put it in some other space where heating up is required.

We will look at heat distribution. So, passive solar sunspace are indirect systems since the heat is produced in the sunspace and then has to be delivered to the adjoining room through a medium. Sunspace integration. The way the heat flows between the spaces is directly dependent on the integration level of the sunspace to the adjacent spaces. Sometimes we can have a lean to space, that is, it can shade adjoining areas of the facade and can reduce natural light into adjoining spaces.

Or the second type is embedded spaces. The sunspace does not restrict daylight to adjoining windows or does not cause any other inconvenience. But it can become self-shading. So heat transfer through conduction among common walls and air circulation through openings can happen. in a sunspace. So, sunspace is a very simple and uncomplicated approach that can be adopted to tap the solar energy in a building.

The greenhouse effect traps the solar energy without the use of any other element except for the transparent component, which makes it a key system in cold climates. For utilizing the solar energy as a passive heating system, it is important to consider storage, distribution, and conservation of the heat, such as the sunspaces. So, sunspaces are very interesting solutions in the energy attitude of solar radiation utilization because they give a lot of energy benefits in terms of reducing the demand for keeping the building warm in winter. These are also designed to collect solar energy to reduce the need for any other auxiliary energy system. Solar energy, which is obtained, depends on the location of the place to understand the intensity of solar radiation.

Some of the solar radiation that is transmitted through the glass can get absorbed by the opaque walls and also through the floors. It can get absorbed by the floors, and eventually heat energy gets transmitted to the adjacent spaces. These are generally used for buildings for heating in winter and cold climates, considering the reduction in the building's heating load, and in the process, the sunspace becomes a passive technology of buildings. Its application in the summer season is not considered because one needs to understand how to utilize the space during the summer when the building does not need to get heated. But the advantage of sunspace over any other space is that the sunspace is a habitable space.

Thermal storage materials in the sunspace collect this heat during the day, and this heat is distributed to adjacent space. But its usage in summer becomes questionable and therefore what can be done is In summers, the sunspace can be impeded from direct solar beams by using shading devices and ventilation by opening some part of the glazing of sunspace as much as possible. Operable vents are often designed at the top of the sunspaces where temperature is highest and at the bottom where temperature is lowest. So, these vents can circulate air between sunspace and indoors or directly exhaust hot air to outsides. They can be operated mutually or with thermostatically controlled motors like mechanical fans.

And this can be used to increase the air circulation to the entire house where natural convection is not adequate. So, a passive solar system with a sunspace which comprises a glazed portion of the structure, is adjacent to a living room. Sunspaces can function as an intermediate space between the inside and the outside. And they can act like a buffer space. A further effect of the sunspace is to shelter the envelope from wind chill and rain.

This can also be used to start natural ventilation. Warm air can flow into adjoining spaces through openable vents located in the common wall at the top of the sunspace. Cool air is returned from the living spaces through lower vents to be heated as part of a convective loop. The other function is that mechanical ventilation can extend the penetration of preheated ventilation into areas of the house that are not adjacent to the sunspace. Heat is collected from the upper part of the sunspace and blown through ducting to other areas of the house where the sunspace is not directly accessible.

So, they are these areas. Sometimes indirect gain can also happen. Heat is transferred to the living room through a masonry common wall. The position of sunspace in relation to the entire building can vary, and some positioning and shape options are shown here. In figure 1, you can see that the sunspace is added; it is an attached kind of a sunspace as shown in this picture.

So, this is attached. Whereas, in option 2, it is an embedded one, as can be seen in this picture. Option 3 is a combination of attached and embedded. So, this is partly embedded, as can be seen in this picture. M4 shows that the sunspace becomes part of the house or it connects two parts of the house.

So, it becomes like one element of the house. The fifth option shows the sunspace to be more like a courtyard space. And the sixth option is that the sunspace encloses the building. So, this is enclosed as shown in this figure. So, these are the ways in which the sunspace can be located in a building.

Let us now look at the limitations of a sunspace. So, first, the sunspaces are easily overheated in summer, and this problem can be resolved by number one, shading from the sun. So, external solar shading from a roof overhang or adjacent louvers can help this. Then second are deciduous trees, though the leafless trees, to an extent, continue to shade. Second is ventilating the sunspace by placing operable vents to the exterior through the roof of the sunspace. These can be automatically opened and should be coupled with vents at low levels to enhance the stack effect.

Third are air permeability and air tightness. Air tightness around windows and doors should be particularly effective to reduce heat loss to the sunspace when the space cools to a temperature below the adjoining living area. And fourth are controls of ventilation. If automatic vent operation is not provided, the building user needs to be fully aware of the need to control the vents properly. Where automatic controls are provided, users should be able to set them to the desired level of comfort.

Thermal mass within the sunspace is another criteria. So the inclusion of thermal mass results from the clear design decisions where the sunspace acts primarily as a buffer space The thermal mass extends the period of heating within the sunspace where the sunspace acts primarily as a passive solar collector and where there is a need for rapid convective transfer to the living spaces, air and not the mass needs to be heated quickly. This process can be increased by the use of light and reflective materials. Let us look at the design and construction and the considerations. So, first is an opaque roof. An opaque roof is needed as it provides insulation, it provides shading, and it restricts daylight to the living areas.

Then there is a need for a glazed roof. When there is a glazed roof, it optimizes solar gain and increases heat loss in overcast conditions and at night. It is prone to overheating and is susceptible to leaking. It is also prone to glare. Now, if vents are placed at the top of the glazing, then air from the room will be pulled away by convection in the air gap between the glazing and mass wall.

This form of passive ventilation is also called the solar chimney. Let us now look at the types. So sunspaces types are according to the type of partition between the sunspace and the adjacent room. So a sunspace with a thermal storage wall and a direct system. So this is a direct system-cum storage wall.

The second one is a sunspace with a transparent partition. So everything becomes like direct transmittance. Third is sunspace with thick thermal storage. And the next one is sunspace with a trombe wall. So, all these variations are possible.

So, basic sunspace types according to thermal mass position. First is the thermal mass in the sunspace floor. The second option is thermal mass in the thick wall between the sunspace and the living area. Third is thermal mass in the sunspace and living area floors. And fourth is thermal mass in the sunspace of the living walls as well as floors.

So, these are the four types of thermal mass positions. Let us now look at case studies. Here we look at a case study, which is a research paper. Now, the main objective of this study is to apply a combination of solar chimney and sunspace to create better thermal conditions in winter and summer for internal spaces. The primary weakness of the sunspace is its ineffectiveness during the summer season, and the main issue is the solar chimney in the building, which has low usage in the cold season of the year. So, this study looks at integrating two passive strategies, that is, solar chimneys and sunspaces, in a building.

But we will focus primarily on the impact of sunspace in this building. So, what was done was a study using simulation as well as field study data collection. And then further simulations were done using variations of the sunspace. So, A is the base case to which sunspace of 4 meter square was attached. And the third option was a combination of sunspace and a solar chimney attached.

So, the first type only is for a 15-meter square comprising of the base case. So, the study showed that the temperature and humidity output resulted from the software on an hourly basis throughout the week in July 2016, and it compared with the experimental results and was found to be fairly in agreement. It was found that the variation among types A and B is approximately 2 degrees centigrade. Though the utilization of a solar chimney in sunspace was there, the room temperature rose due to improvements in the building heating process through the roof. The mean temperature variation between type B and type C is about 1 degree centigrade, but it is not much of a concern to us here because we are not studying the impact of solar chimneys. So, this variation between type A and type B is of concern to us in this lecture.

And the outcomes indicate that the sunspace system decreases the indoor temperature by 2 degrees Celsius in the hot season and increases it by 3 degrees Celsius in the cold months. And if you look at the annual cooling and annual heating load, there is a difference in the annual cooling and annual heating load as well as annual energy consumption when sunspaces are used as compared to the base case. So, sunspaces are a system—a passive system—that is often used in residential buildings because they can conserve energy. They give us spaces that can be utilized. They cannot provide the best of indoor conditions, but they have a significant contribution to conserve the energy-generating products used for heating and cooling.

Further research needs to be done on sunspaces in terms of the position in relation to the sun, the size of the glazed surface, the type of glazing, the thermal mass sizes, and the use of wearing materials. So, in today's class, we saw sunspaces comprehensively as an advanced passive technique. will continue this class with yet another advanced passive technique next class. Until then, thank you.