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

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Lecture 01

Thermosiphon Solar Air Heater

In today's class, we will look at another passive. We will look at another advanced passive strategy that is also related in a sense to the trombe wall concept. It is called a thermosiphon solar air heater. So we know that there are three broad ways through which we can harness the energy of the sun into the building. So the sun could heat the living areas directly with a direct solar gain system. where the heat in this area is re-radiated back into the space by the glass surface.

So, directly, heat gets radiated inside or through wind. So, a dense construction material such as the wall or roof is heated by an indirect solar gain system, which transfers the heat through the material into the inside of the structure. In indirect solar gain, what happens is the structure, instead of the solar gain hitting the surface directly, there is yet another layer of wall behind creating a space like this. So, solar radiation that strikes this glass wall does not directly hit this wall because it hits this glass surface, and the heat gets trapped between this and the air gets trapped between this, and that air moves in this manner.

So, this is the indirect solar heat gain system. The third one, which is of interest to us now in today's class, is a fluid or vapor that is passively moved by natural or forced convection to transfer heat from or to the living space with the help of an isolated solar heat gain system, which has its essential components located apart from the building's primary living area. So, in this third case, like the first case, the house exists. Like the first case, the house exists in isolation. but there is a separate structure there is a separate structure which actually holds a lot of heat and this is called as the isolated heat gain because This place is isolated from this space, which is isolated from the main house.

So the terms thermo and siphon are combined to form the word thermosiphon. A siphon is a basic apparatus that uses tubes to move the liquid. It is a curved tube that allows liquid to be dragged through it at the lower level and over the edge of one container using a pressure differential. Here there is no need for a pump as the liquid flows against gravity and upward. Siphons rely on gravity and differential pressure.

Lower pressure at the top of the siphon is caused by gravity pulling the liquid down on the exit side of the siphon. A liquid from the upper reservoir is then forced up into the lower pressure at the bottom of the siphon and eventually over it by air pressure. Thermosiphons operate on a similar concept, but heat is used as a driving force rather than air pressure. Hence the name thermosiphon. Let us look at the principle of thermosiphon in our context.

A thermosiphon is a passive heat exchange device that circulates a liquid or vapor naturally through convection. It does not require a mechanical pump or other moving parts. The circulation of liquids and volatile gases in heating and cooling applications such as heat pumps, water heaters, boilers, and furnaces is yet another usage for thermosiphons in addition to passive heating. The most well-known kind of solar water heaters in use today operate on this idea. The idea behind a thermosiphon solar heat collector is that hot air rises because it is lighter than cold air, which falls and is drawn back to the thermosiphoning system.

So, a thermosiphon system comprises of a separate isolated unit. Isolated unit. on which solar radiation falls. The air here gets heated, moves up to warm the room, cool air settles and comes through this, which in turn gets heated, and the cycle continues. When there is a need to cool the room, the solar radiation keeps the room warm.

The inlet to the house is closed, and the outlet to the outside is open, and the warm air escapes. This causes a vacuum, inviting cooler air from inside, and this cycle happens. There could be other vents that can keep the windows ventilated. Let us look at its working. For a thermosiphon, there is a need for a solar collector.

So, a solar collector is one that lets solar energy through a glass or polycarbonate sheet that is positioned on the side of the building facing the equator. The collectors are placed on the equator side so that it can collect maximum solar energy. This heat is then absorbed by the absorber. So we need a solar heat absorber, which is a thermal mass or a black surface that absorbs solar radiation and warms the air inside the thermosiphon. The insulation placed at the back of the absorber prevents heat loss through conduction.

The insulation, which is the third element, is used to reduce heat loss, and the insulation is kept or placed behind the absorber on the other side of the solar collector. So, this is the solar collector. And this is the absorber, which is a thermal mass. Then vents are placed to let air enter and exit the thermosiphon system, and they are there to intake and outlet the vents at the bottom and top, respectively. ducts may be optional.

The warm air can be dispersed throughout the structure using insulated ducts. Dampeners are needed to stop air from flowing backward at night or on overcast days. These dampeners are installed on the exit ducts. We will now look at the types of thermosiphons. From this slide, we can see the different types of thermosiphons.

The first is the window box collector. Now these differ based on the method of collection. the location and the cost. So, the window box collectors are portable, easy to construct, and low-cost collectors that can be placed in the window whenever required and do not need any special considerations during the design stage. These cannot be used to store heat for later use.

It is preferable for locations that require heating for only a few months throughout the year. Second is the thermal mass solar air collector. The second type. Thermal mass solar air collector. These have a thermal mass.

that store the heat, the thermal mass that stores the heat, which is collected by the solar collector for a later use. These require a lot of pre-planning. They take up space and are expensive as the air is circulated through the building structure. This type of collector is preferred for locations that require heating all year round, and there is also a need to store the heat before it is dispersed. The third is a thermal mass solar air collector with an earthworm.

This is the third one. So, this is a variation of the thermal mass solar air collector except that there is an earthworm on one side, which acts more for insulation too. And then the fourth is the wall solar air collector. This type can be installed on the equator-facing blank wall or any building during construction or is a later addition. It does not take up much space and is relatively cheaper as compared to the other types. Let us now look at the advantages and limitations of thermocycles.

First is the cost effectiveness. There are no operating or electricity expenses, which adds up to substantial savings over a period of time. The second is dependability and low maintenance. These are reliable, and maintenance requirements are very minimal, especially since we have a straight-forward design without any movable parts. Third, these are sustainable solutions, as they lower carbon impact by utilizing renewable energy sources like the sun and natural convection methods.

Fourth is comfortable heating. Compared to forced air systems, it distributes heat gently and evenly, making the atmosphere cozier. Fifth is its versatility. Now this system is able to accommodate different building types and heating requirements. These can be added to the building later without requiring any unique or complex modifications to its structure or design.

The limitations include first a limited heating capacity. This system might not be enough for huge spaces or bitterly cold climates. Second are the spatial requirements. Large collectors or duct work may be needed depending on the design. Third is its dependency on performance.

It depends on elements such as solar radiation and appropriate system architecture. Fourth is its slower heat-up time. It could take longer to reach the desired temperatures within this system than with forced air systems. And fifth is lack of thermal storage. This method lacks thermal storage that is released later in the night, in contrast to the trombe wall.

Let us now look at a case study. This case study was on solar passive heating through a thermosiphon air panel. A research done by R L Shawani, Bansal, and Soda. So, in the cold desert regions of North India, thermosyphon air panels were mounted on a building's south side, and this was utilized for solar space heating. In order to forecast the performance of these panels, a simulation model was presented in this research. The performance has been numerically evaluated, which has a maximum and minimum temperature of minus 2.

1 degree Celsius to minus 14.2 degrees Celsius, respectively. The study showed that a thermosiphonic air panel is a simple and effective device that can be incorporated into south-facing houses for collecting solar heat during sunshine hours. The system is suitable for cold desert climates. The average efficiency of the system comes out to be between 30% and 37% depending upon operating conditions.

The total energy collected could be 2.3 kilowatt hours at an average efficiency of 32.5%. It is found that if the inlet of this system is exposed to the ambient, its efficiency is slightly higher and approximately 37.8%. Let us now look at the application of this system.

A window box thermosiphon solar air heater has been built by Professor Thomas Jenkins at New Mexico State University to demonstrate this concept. The movable device has been designed such that the vents fit into the top-hung window of the building and the rest of the device is outside under direct sunlight on the equator-facing side. Thermometers were attached to the inlet and outlet ducts to measure the temperature difference, and it was found that in midday in late October, a difference of 50 to 60 degrees Fahrenheit, that is, 10 to 15 degrees Celsius, was observed. The device has been made from easily available materials like plywood for the box, a metal sheet that is painted black that acts like an absorber, and a glass covering that works like a solar collector. This is a completely customizable device that can be designed according to the width of the window and height of the sill level.

Another application is the house in the city of Bozeman, Montana, in the US. Here the winter temperature can go as low as minus 10 degrees Celsius. Taking advantage of the large south-facing walls, a wall thermosiphon air heater has been used. The system is made up of a series of 4 feet wide by 2 feet by 6 feet frames attached to the sides of the buildings. A series of vents were cut into the building at both the top and bottom of each frame, as shown here.

You can see how this is cut. Within each frame, black aluminum window screen mesh is suspended, which acts like an absorber, which is the absorber. Clear corrugated polycarbonate panels cover the entire frame. So, this is the polycarbonate sheet. Simple back flaps automatically prevent reverse airflow at night or on cloudy days. During summers, the higher angle of the sun prevents unwanted heat from being created.

During winter, the reflected sunlight from the snowy ground also helps in heating up the spaces. A temperature difference of about 26 degrees centigrade is observed between indoors and outdoors. So, this experimental setup had a data logger. And it showed that the system is able to produce 300 to 400 dollars worth of heat per winter. So, today we have seen a new concept of thermosiphoning, which is a derivative of isolated heat gain.

In this lecture, we saw the different types of thermosiphoning systems, the simplest and easiest of which uses air as a carrier but is temporal. The second type is the one where there is additional thermal mass. By having an additional thermal mass, the system is able to store the heat energy and use it whenever it is needed. depending upon the requirement. We also saw a few case studies and some research work that shows the efficacy and the systems used in places that are extremely cold.

We also saw the advantages and disadvantages of using this system. So, this direct heat gain system known as thermosyphon is proven to work based on the research done and also based on the case studies and applications that we studied. We will stop today's class with this, and in the next class we will continue with yet another topic on advanced passive strategies. as future-proofing to achieve bioclimatic strategies. Thank you.