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

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Lecture 01

Solar Chimney

Hello everybody. In the last class, we saw an advanced passive strategy, which is earth-berming and earth-sheltering of buildings. In today's class, we will see another advanced passive strategy as part of this course: bioclimatic architecture, future-proofing with simple and advanced passive strategies. In this class, we will see about solar chimneys as an advanced passive design strategy. This is used for space heating and cooling application. So, what is this? What is a solar chimney? A solar chimney is a natural way of ventilating a building using passive solar energy.

It is a vertical shaft utilizing solar energy to enhance the natural stack ventilation through buildings. This system is a kind of modified trombe wall. A solar chimney is essentially a collector panel with minimal thermal inertia, which is the ability of a material or surface to resist changes in temperature. Materials with low thermal inertia heat up and cool down slowly.

On the south facade of the building is what it is normally kept. It absorbs incident solar radiation and heats up the air inside the space. Stack ventilation uses temperature differences to move the air. Hot air rises because it is at a lower pressure. For this reason, it is sometimes called buoyancy ventilation.

The stack effect, or the hot air rises due to the buoyancy, and its low pressure sucks in fresh air from outside. So, this buoyancy ventilation is what it is called. Stack ventilation happens because of buoyancy ventilation. When cool air enters inside the building from outside, it becomes warm and goes up because the hot air is lighter and the cool air is heavier. To remove the hot air Openings are provided in the upper part.

Because of this, the lower vacant space is taken by the cooler air, and this cycle gets repeated, causing natural ventilation. Let's look at the working principle of a solar chimney. The solar chimney operates on the principle of buoyancy or stack effect. The chimney is coated with a black material to absorb maximum sunlight, with openings at the top for hot air exit. So, the chimney is actually a long stack that has openings on the top, which enables the hot air to escape. The chimney can also be used to recirculate hot air for heating in cooler areas. But if we are looking at cooling of buildings, then hot air is warm and it rises up, and when there is a vent, the hot air escapes outside. And it is replaced by heavier, cooler air through openings at a lower level. And therefore, at a working plane, you have ventilation and access to cool air.

Both have become available. So, in winter, we need to heat the building. So, for heating a building, when the solar radiation hits the black surface of the chimney, the air inside becomes warm. The top exterior vent of the chimney is closed. And what happens? The heated air is forced back to leave in the space.

So, if there is a vent, that vent is not kept open but the vent is closed. Once the vent gets closed, the air is forced to enter the room. Also, solar radiation can also make the building warm, so what happens is when this chimney is coated black and then the solar radiation hits, this place gets warmer throughout the day, even at night It continues to give in warm air inside the cold room In summer, the vent has to be opened. So, when you open the vent in summer, there is movement of air this way, causing a vacuum, and cold air or cool air comes to replace the vacuum that is created because of the vent. Let us now look at the advantages of solar chimneys.

A solar chimney is simple to use. It is a very simple technique, easy to use. It is very easy to maintain. It has low maintenance costs. It saves electricity.

And has absolutely no harmful impact on the environment, as it works on the nature of the environment. That warm air rises, cool air descends, dark wall absorbs more heat. What are the disadvantages or limitations of solar chimneys? It has a high initial investment cost. Second, it is recommended for new houses that have good insulation and air tightness, not as a retrofit measure. Let us look at the application of solar chimneys.

A solar chimney can be integrated into buildings as a natural ventilation device. Sunrooms can be designed to function like solar chimneys. It can help in the generation of electricity by utilizing less electricity. These can be integrated into buildings as a heating device. Let us look at the factors that influence the use of solar chimneys.

So, what all factors govern its performance? So, the factors that govern are the geometrical parameters. Geometrical parameters mean the geometric changes are the most intuitive method directly affecting air flow behavior and building response. First is the chimney height, or the height of the stack when we look at the stack chimney height. Second is the size of the vent on top, third is the cavity or air gap on top, the inlet and outlet location, so at what height does the air enter inside, the opening or window area position, room layout and volume, the volume of room that it caters to, whether it is this volume, this volume, or this volume, and then the installation conditions. According to the location of installation in the building, the solar chimney is divided into a vertical wall and a rooftop solar chimney.

So, whether it is at an inclined angle, whether it aids in solar collection, its orientation, and so on. There are other external environmental factors too. The external environmental factors include -But the role of natural ventilation system is heavily dependent on the local climatic conditions. So, solar radiation intensity—how strong is the intensity of solar radiation? External wind intensity and direction could dissipate the intensity of solar radiation. Third is the relative humidity.

Fourth is the ambient temperature whether the outside temperature is 49 degree Celsius or 18 degree Celsius, it matters. Indoor heat source's location. Then the material uses the characteristics of the material, which will affect the thermal conductance. convection and radiation. So, what are the building materials used? The building envelope material, the glazing wall, and the solar absorber—all of these contribute to the thermal mass, and then the occupant's behavior. People's habit includes the operation of the ventilation system and response to temperature, etc. This will cause the actual performance of the ventilation system to differ from the simulated or estimated performance. So, if we look at overall, what factors influence the performance of a solar chimney? It is first the geometrical parameters pertaining to chimney configuration and room configuration. Second are the installation conditions.

How is it installed? Third is the external environment, the factors governing the outside environment. Fourth is its material usage; what is the thermal mass of the various associated built forms?, and fifth is the occupant behavior. So, the chimney configuration comprises of these five aspects, the room configuration comprises of these two aspects, and the installation conditions comprise of these two aspects. The external environment comprises of these five aspects, while the thermal mass is the sum of all the built forms involved. So, these are the factors that influence the performance of a solar chimney.

Let us now look at the case study. The first case study that we will see is of Avasara Academy in Pune. Now, this is an academic institution. It is a new construction in a probably Pune, we can say moderate between moderate to hot and humid condition. So, this is an example of a contemporary design that integrates climate-responsive design strategies.

So, this building is a naturally ventilated building, and it is used as a combination of passive heating and passive cooling systems, thus eliminating resource-draining mechanical systems. So, passive heating and cooling systems are designed with earth ducts. structurally integrated vertical cavities and solar chimneys to induce ventilation in each building, lowering the indoor temperature by 5 to 9 degrees Celsius during uncomfortably hot summer months. So, you can see in this building that there is a solar chimney right at the center. Here are the solar chimneys located.

So, convection causes the stale air from every space to passively transfer through the exhaust grills at ceiling level into three distinct exhaust cavities positioned at the center of the building. These exhaust cavities are integrated into the building's structural core and eventually extend as solar chimneys above the roof level. These chimneys are broad with glass on three sides. A nearly five-meter-tall concrete wall in the back and lowered grills on the top are also placed. The heated air is directed out of the building by this solar-powered assembly, which also acts as a passive air mover, naturally cooling the entire space.

Because the suggested design is entirely passive, it reduces the annual energy costs by 80 percent. So, here is the solar chimney, which, because warm air is lighter, rises in the room, and there is a vent through which the warm air rises and leaves the chimney. Whereas the cool breeze comes from, there are specific outlets for the warm air to leave through the chimney and specific inlets for the cool air, creating an air movement because of the buoyancy effect. The second case study that we will see is the Powell Elementary School.

It is an educational institution. And it has a solar chimney. This is the first solar chimney in a DC public school system. And this is found at Powell Elementary School. So these were created to mimic and enhance a system that was comparable to one of the old 1929 buildings, which was an inspiration for the solar chimney to be placed in this building. This was done to reduce the energy usage and make this building more energy efficient, coupled with other passive design techniques.

So, CFD models were used in the construction of the solar chimneys to produce cool, fresh air without consuming any extra energy. The classroom wing solar chimney alone has resulted in about 6 percent energy savings. So, here you can see how it works. It works because the open windows in the classroom let in fresh breezes. The hot, stale air flows out of the classroom into the solar chimney through the inlet at this point, and the hot air leaves the chimney like smoke from a fireplace.

So, it is the same concept: providing an appropriate inlet and opening it at the right time for the breeze to flow out. So, utilizing the stack effect and the sun's heat, the solar chimneys are equipped with exhaust turbines, which circulate the fresh air across a crowded space. So, here are the operable windows through which fresh air comes in at a lower level. Then there is the ventilation flue or the solar chimney. Then there is the exhaust turbine, which sucks in the air—or sucks out the air rather.

Then there are other things, like indicator lights. and then the prevailing breeze, which flows in with fins for shading, and then there are other trees for shading and a green roof on top. So, the air moves in, and because of the chimney, the air is able to move out as the solar chimney because of the glass here. When solar radiation strikes this surface, this is the solar radiation causing this air to become warm. So, it is the warm air here, and this circle continues.

So, every classroom's rooftop weather station has indicator lights connected to each solar chimney when the wind speed, humidity, and temperature are ideal. So, these meters, these indicators, show the effectiveness of the solar chimney. So, when it is appropriate, the pupils open the windows. Based on what the indicator says, the window or the inlet is opened, and cool air is replaced with stale air by the solar chimney. So, these indicators indicate whether the air is stale or whether the air is good enough, and if the air is stale, the students just have to open this inlet, and then the air gets replaced because of the solar chimney.

So, today in today's class we saw another advanced passive strategy called the solar chimney. And solar chimneys function on the principle of Guyan-C ventilation. It functions on the principle that warm air rises and cool air settles down. And also, inlet air should be at a lower level, and outlet air should be at a higher level. So, when the air inside the room becomes warm, the solar chimney in turn is already made warmer so that the movement of air is already instigated.

The warm air escapes to the solar chimney and from the solar chimney to the outside, and therefore it is important to have vents in the solar chimney. From the vents in the solar chimney, hot air escapes. That creates a vacuum, like in the lower areas, and if there is an inlet at a lower level of the room, fresh air from outside flows in through the inlet and escapes through the outlet of the solar chimney due to buoyancy. So, this is what we saw today with some case studies. With this, I will close this class and we will meet in the next class with yet another topic on advanced passive strategy, which requires a contraption to collect the heat energy, store the heat energy, and dissipate the heat energy. Thank you.