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

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Lecture 04

Earth Sheltering

Dear students, in our last class, we saw what happens if we are not conscious and we design buildings according to simple and advanced passive techniques, and one of its impacts is the urban heat island. In our last class, we saw what an urban heat island is, its cause, how we can reduce its effect, and what happens because of UHI. We will now move to the advanced passive techniques that can be used in architecture. The first one today that we will see is the earth sheltering. So, let us have a look at the advanced passive technique of earth sheltering. Now, what are earth-sheltered buildings? When a structure has a sizable quantity of soil or substrate that is thermally relevant in contact in physical contact with the exterior envelope, that is, when the earth is pressed up against the wall on its roof or the building becomes subterranean partially or completely, the building is termed as earth-sheltered.

Earth coupling is where concrete floors and sometimes even walls are in direct contact with the earth. In a well-insulated, properly shaded house, this draws up the stable, deeper ground temperature to the surface of the floor, which gives the house a head start in regulating its temperature. You can see in these case studies how the hobbit house is camouflaged and covered with soil, and it merges with the surroundings. Similarly, the encaved house in Greece becomes part of the landscape as it is buried, the back of the house is buried, or it is inserted inside the hillock.

And then the robo ranch is again camouflaged in the landscape as such. If we look at the history of this technique. So, throughout history, humans turned to the earth for protection against climate and extremes and dangers. In around AD 800, people in Cappadocia, Turkey, carved underground chambers to protect themselves from invaders and because of scarcity of materials. In Matmata, Tunisia, and Giryan, Libya, residents carved atrium houses below ground to combat extreme desert temperatures.

In China, provinces like Shanxi, Gansu, and Human have been digging entire cities underground since the 1920s, with over 10 million people underground. In the American Midwest, the sodhouse and dugouts were built in the 1800s to address severe weather conditions, a lack of building materials, and a fuel shortage. Let us look at the types of earth sheltering. Because of the earth's physical properties and potential for thermal conservation, earth shelters are now defined as buildings that use the earth's mass against building walls as an external thermal mass. This minimizes heat loss and keeps the temperature of the interior air constant throughout the year.

There are mostly these three types of earth sheltering. An earth-sheltered building constructed completely below grade that is subsurface appears subsurface on one side and bermed on the other side. But actually it is completely underground. This is referred to as an underground structure. A sheltered building that is constructed completely below the ground, like a chamber, is called an underground earth-burnt structure.

The elevational floor plans have one whole building face exposed while the other side and sometimes the roof are covered with earth. The penetrational designs are built above grade with earth-burnt around and on top of it. The entire building is covered except at windows and doors where the earth is retained. So, you have structures that do not have even a single surface; no surface is exposed. Whereas, you could have an atrium type where one roof is outside the earth.

There is one elevational where one surface is exposed outside and then the penetration type where actual livable spaces are inside but multiple other ways of entering the building. So, multiple surfaces to enter the building are available. Whereas, if we looked at bermed structures, bermed structures again are like this: they look like they are underground, but a part of it is exposed outside, and most of the building is covered by the soil. So, an underground earth shelter refers to a fully subterranean structure or house built below or at a surface level. It can feature a chamber or a yard design, providing an open feeling despite being underground.

So, typically constructed on a flat site with major living spaces surrounding a central outdoor courtyard. So, it can be something like this where it is fully covered with soil on one side and then one surface is exposed, or it is fully inside the earth with only the atrium being exposed, and exposure to the outside is only through the atrium. Something like this through the atrium. So, the windows and glass doors on the exposed walls are limited, especially in dense development or areas with undesirable views. Passive solar gain may be constrained due to window positioning, and issues like patio drainage and snow removal should be carefully addressed in this kind of bedding.

If we look at the layout and features, rooms requiring heat, such as bedrooms and living rooms, are often located near the center to maximize warmth. So if this is the central opening, then areas that require warmth and are habitable are primarily exposed to this part. It is a spread-out design, and these may make them less efficient at capturing warmth. Lack of proper construction could lead to issues with humidity, condensation, or even mould. Underground homes are commonly built in warmer climates like hot, dry Mediterranean to counter this problem of condensation, high humidity, and mould development.

The ventilation and heating solutions for these houses are that the homes without a yard or chamber can use skylights and other ventilation methods. The next one is a bermed earth shelter. Bermed houses can be built above or slightly below grade with at least one wall covered with earth. So, the entire building is not covered but one wall; one or two walls can be exposed, and the remaining thing can be subterranean. Elevational berm design exposes this one face of the house, covering the other sides and sometimes the roof with earth for protection and insulation.

The exposed front, usually facing south, allows sunlight to illuminate and warm the interiors. Earth assists in managing storm drainage, sloping away from the home, and additional pipes and drains can be added if necessary. When it comes to ventilation and moisture control, strategically placed skylights ensure adequate ventilation and sunlight in the house. Burmed homes encounter fewer moisture problems compared to underground homes since they are either above or only slightly subterranean. Then we have the in-hill earth shelter.

The shelter is set on a slope or hillside with earth covering both the roof and the walls. Ideal application is on a hill facing the equator in the northern hemisphere, away from the equator in the southern hemisphere, or east just outside the tropics. Practical considerations are that they have only one exposed wall facing out of the hill. The other walls are embedded within the hill. Most practical and energy efficient in cold and temperate climates, these are much suitable for these climates.

One of its distinctive features is that up to three walls can be covered and one exposed for doors and windows or for entering the house. Sunlight absorption and layout happen because the exposed wall with windows can bring in passive heat with absorption from the sun. Rooms needing natural sunlight, such as bedrooms, kitchens, and living rooms, are closer to the exposed wall, while other rooms like storage areas or bathrooms are farther away. Again, this kind of in-hill earth shelter has issues of condensation or mould in areas that are very damp and humid. Let us look at the working principle.

At about 4 meters below the earth's surface, the ground temperature is fairly stable throughout the year, and it equals the annual average temperature of that place. Low-temperature systems such as passive annual heat storage and annualized geosolar use the soil adjoining the building as a low-temperature seasonal heat store, reaching temperatures similar to average annual air temperature and drawing upon the stored heat for space heating. Such systems can also be seen as an extension to the actual design of the building, as the design involves some simple but significant differences when compared to traditional buildings. Conduction from the soil in contact with the building and infiltration is less. The temperature can be maintained indoors as it is closer to the annual average temperature.

So, what happens is when the exterior temperature is about 35 degree Celsius and the annual average temperature of the place is about 20 degree Celsius, the house, which is partly burnt Its indoor temperature becomes 28 degree Celsius because it passes its heat to the soil and in that process it becomes cooler. If you look at the completely submerged atrium design kind of an earth shelter, you can see that if the exterior temperature is 35 degrees Celsius and the earth temperature is 20 degrees Celsius, the internal temperature can be maintained at 24 degrees Celsius as compared to the elevational house. because the prospects of outdoor solar radiation get minimized because it is an atrium concept. Whereas, here the wall and/or the roof are exposed to the outside. Now the vice versa is also true.

If the outside temperature is 10 degrees Celsius, the earth temperature is maintained at 20 degrees Celsius. The internal temperature would be anywhere between 15 to 18 degrees Celsius. Either way, it is a win-win situation. In passive annual heat storage, solar heat is directly captured by the structure's surface through windows and other surfaces in summer and then passively transferred by conduction through its floors, walls, and sometimes roof into adjoining thermally buffered soil. It is then passively returned by conduction and radiation as those spaces cool in winter.

The annually geothermal soil uses a separate solar collector to capture heat. The collected heat is delivered to a storage device such as soil or gravel or some hotbed or some such structure. Sometimes even a water tank, which is either passively cooled by the convection of the heat transfer medium, such as air or water, or actively cooled by pumping, stores energy. This method is usually implemented with a capacity designed for 6 months of heating. So this house is warmed by earth all through during winter also. But these houses have to be super insulated in roofs and walls. The warmth of the earth in summertime is tapped through tubes in soil, and the metal roof serves as a solar collector. Through tubes, the soil is kept warm, heated, and kept warm. And during winter, it radiates back to the house, maintaining the indoor temperature of the house. But in that process, insulation of the house of all the envelopes of the house is very important.

Let us look at the advantages and limitations of earth-sheltered houses. The advantage is that there is a decrease in the building's average thermal load as a result of increased earth's thermal resistance and less outside air infiltration or air leakage. Once more, summer and winter variances quickly disappear as one descends further into the ground, resulting in nearly constant temperature at a few meters below the surface throughout the year. Airborne noise and surface vibrations are absorbed by the soil. It serves as a shield against ultraviolet deterioration against the vagaries of weather like wind and storm.

These buildings require additional heating, which can be supplied by direct solar gain through the windows that are protruding above the ground and are located close to the roof. When further cooling is required, the structure may draw in outside air through the subterranean ducts where the temperature is low. Evaporation may be used to cool the air passing through the duct if needed. In cold temperatures, the fresh outside air might receive some preheating from the same ducts. These structures also have a disadvantage.

The need for high-quality waterproofing and insulation to arrest exposure to ground moisture and the need for a higher level of design and supervision in small-scale construction become important. Let us now look at case studies. The first one is Sangat, Ahmedabad.

It is the office of Dr. B.V. Doshi is located in a hot, dry climate. So it is located in Ahmedabad by Dr. B.V. Doshi. Has a built-up area of 584 square meters, approximately. And Sangat means moving together with participation. So, Sangat is an architect's office, which is supported by many passive solar passive techniques. So, the design concerns of climate such as temperature, humidity, air flow, etc has been used. This structure is closely integrated with outdoor spaces. The west and south facades are shaded by dense trees, and wind flows from the west and southwest sides have been tapped to create a central open space through which the wind can flow unobstructed. The site is a quadrangle overlooking south over a road. There has been extensive use of walls; grassy steps are used as an informal amphitheater, which also acts like a roof garden. They have used a lot of diffused light and vegetation, as well as water bodies.

So, the design concerns of climate all climatic elements have been addressed. Extensive use of vaults is done in this design because vaults do not have a flat surface, and incident solar radiation is minimal with vaults. The main studio is partly below the ground and subterranean or sunken. This building is raised on a plinth and buried in the ground with very little mechanical. Special materials are used, resulting in this building being low-cost with a lot of use of vegetation and water bodies.

Because the building is partially subterranean, the building is partly sunken. A temperature difference of about 8 degrees Celsius during the hottest part of the year is noticed with a time lag of nearly 6 hours. Time lag is the difference in time between when the outdoor reaches its peak and the indoor reaches its peak. This building is largely buried underground to use earth mass for natural insulation. This is the studio space, which is buried underground with skylights.

The external walls of the building are nearly a meter deep but have been hollowed out as alcoves to provide storage and then become an insulative wall with efficiency of space. So, with this, we conclude this lecture on earth sheltering. To summarize, we saw that earth shelterings are of two types primarily. The first type is the underground type, where the entire structure is buried inside the earth, and due to that, the structure remains insulated from the outside. If the outside temperature is say 38 degrees Celsius and the annual average temperature of the place is 25 degrees Celsius, you can rest assured that the building is nothing more than 26 to 28 degrees Celsius.

But this kind of building also could have issues if it is done in a humid place, which causes the building to have mold, condensation problems, and so on. The basic principle is that the subterranean temperature is more or less constant irrespective of the outdoor temperature. But during winters, if the outdoor temperature is say 16 degrees Celsius, the subterranean temperature would still be approximately 25 degrees Celsius to be 24 degrees Celsius, in which case the house would have its temperature again somewhere around 24 to 22 degrees Celsius. It would not be impacted by the lower temperature outside or the higher temperature outside because the soil temperature is higher than the outside temperature during winter and lower than the outside temperature during summer. And therefore, having a subterranean house would ensure that the insulation of the soil plays up.

But since it is unhealthy to live in an environment that does not see sunrise or sunlight at all or has no exposure to natural light and ventilation, a small variant of this concept, taking the same concept but varying it in terms of architectural design, happens when one of the surfaces is exposed to the outside and the other surfaces are bermed. So, what happens is that solar radiation can penetrate through this surface. Also, on this surface, because of this surface, there is a visual connection to the outside. A visual connection is established to the outside world, and this acts as a medium between the completely submerged subterranean house and the completely exposed house because it offers the advantage of both.

So, these are the two types of earth sheltering. And if and these earth sheltering should be done very carefully in humid environments; otherwise, the problems of condensation and mold development start, and they are best and ideal for hot and dry conditions. The concept of this is adopted from traditional architecture. So, with this, we stop today's class and we will move on to another advanced passive technique in the next class. Thank you.