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

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Lecture 01

Green Roof

Hello everyone. So, we had seen some advanced passive techniques in the last few classes, and we continue with looking at another advanced passive technique. In this class, we will look at an advanced passive technique called green roof. It's a passive cooling technique, and it is a technique that is not only advantageous to the building but can be advantageous in even altering the microclimate of the place. Which means this technique can be useful even at an urban level. What is a green roof? So, a green roof is a roof that is partially or completely covered with vegetation and soil.

Vegetation is planted over a waterproofing membrane. Why should we use a green roof? We should use green roofs in order to, number one, moderate the heat. Number two, green roofs can provide thermal insulation. Evapotranspiration happens due to the green roof.

Moisture can get retained, and heat load can get reduced dramatically, especially in the hot climate, irrespective of the humidity. Stormwater management has to be taken care of, roof membrane protection should be given, there is considerable noise reduction, air quality gets improved, energy consumption gets reduced, and urban heat island mitigation happens. So, let us now look at the history of green roofs. Actually, it all started with a green wall. The history of the green wall dates back to 600 BC with the hanging gardens of Babylon.

So in 600 BC there was the hanging garden of Babylon. The history of green walls dates back to 600 BC with the hanging gardens of Babylon. Green roofs were used in ancient structures to cover with plants for agriculture, dwellings, and ceremonies. In about 1500 AD, around that time, the America Greening Building started with the development of hydroponic systems on green walls. The history of green walls dates back to 600 BC with the hanging gardens of Babylon.

Green roofs were used in ancient structures covered with plants for agriculture, dwellings, and ceremonies. In the 1500s, a lot of greenery was used over the buildings, which provided insulation as well as aesthetics. In the 1930s in America, greening buildings started with the development of hydroponic systems on green walls. Because of this, soilless agriculture and use of vertical greenery were combined. In the 1960s, green roofs saw further development in Germany, and the trend then spread rapidly.

Now, green roofs have trended globally, with around 75% of Europeans living in urban areas where they impact social, health, and ecological aspects. Green roofs act as nature-based solutions to address challenges like noise, air pollution, changing weather, and loss of natural habitats. There are two major types of green roofs. One is the extensive green roof and the intensive green roof. An extensive green roof is characterized by the following:

It needs shallow soil depth, typically 2 to 6 inches. It can be done on lightweight construction. It has low-maintenance vegetation such as sedums, grasses, and moss. Its advantage is that it is well suited for retrofitting existing structures because it can be laid on lightweight construction, which means the dead load is very low. It requires minimal maintenance, and it provides thermal insulation as well as storm water management.

If we look at an intensive green roof, this is characterized by deeper soil depth, about 6 inches or more. So, it becomes heavier. It supports a wide range of plant types, including shrubs, sometimes small trees, and perennials. Its benefit includes creating usable space for gardens, parks, or recreational areas. It offers a diverse range of plant species and provides enhanced insulation and stormwater management.

Let us look at the green roof system elements. A green roof consists of both horizontal elements and traditional roofing components. There are three distinct layers in the green roof from the bottom. The first is the structural layer, the second is the growing medium, and the third is the vegetative layer. The structural layer comprises the roof deck, a waterproofing layer, and an insulation-protecting layer.

So, the structural support, the vapour barrier, the thermal insulation, the root barrier, the drainage barrier, the filter membrane. All of these combine together to form the structural layer. Then comes the growing medium. This growing medium may or may not be soiled. Because if hydroponics is used then water could be the growing medium.

And third is the vegetation layer. These are the different layers or different components of an extensive green roof. Let us look at the structural layer in detail. It comprises of number one, the roof deck. The foundation of a green roof is made up of materials like concrete or wood.

This supports the weight of the green roof. Concrete decks are great for green roofs as they do not require any extra support systems. The second is waterproofing. Because of waterproofing, moisture or rain is kept away from the building. This is important because as we water the plants, the moisture could seep into the main structure if we do not waterproof it.

The types include built-up, single-ply, and fluid-applied membranes. Third is insulation. Green roofs, these require some insulation but they cannot replace. Green roofs themselves add some insulation, but that cannot be replaced by dedicated insulation. How well they insulate depends on the soil depth as well as moisture.

Fourth is the protection layer and root barrier. So, in green roofs, the protection barrier shields the structure from living and growing materials. Roots can damage the waterproofing membrane, so a root barrier is crucial. This is placed above the membrane. It prevents roots from penetrating and causing leaks.

Then there is the drainage course. In a green roof, the drainage course helps the water move sideways. This prevents too much water and gives roots space and keeps them ventilated. Placed over the concrete slab, it covers the whole roof. And then sixth is the moisture retention layer.

This is important for plant growth. This layer stores water. It is like a sponge above the drainage layer, helping plants to grow well. Then comes the filter layer. So in a green roof, the filter layer is like a guard.

It keeps the soil in place and stops it from washing away. Made of a tight fabric or mat, it lets water through but stops tiny soil bits from causing problems. So, here are the pictures of what a root barrier, a drainage map, a filter fabric, and growing medium look like. Next is the growing medium. Now the growing medium holds enough water for plants but also lets the water drain.

It needs to absorb nutrients, keep its volume, and be light. So instead of heavy soil, organic matter is often used to reduce the weight and save cost. The best growing medium balances water capacity, drainage, fertility, and density. It should also withstand heat and other roof-damaging factors. A simple example of what a growing medium is is the use of a mix of coco peat, compost, and soil.

Cocoa peat is an organic matter. It is extremely light in weight. Compost again is an organic matter, very light in weight. Soil is used more like a binder for both of these. So, a

growing medium. One example is a combination of cocoa peat plus compost, compost can be vermicompost plus soil, red and black soil.

And then the third layer is the vegetative layer. It is important that we select the right plants for how the roof looks and helps the environment, and also to understand what our expectations are from the green roof. Whether we would want to cultivate something out of it or if it is only for aesthetic and environmental purposes. So there are different ways to grow them.

There could be mats or seeds. Each has its own cost repercussion. So, sometimes vegetation is available as mats, which can be rolled over the soil layer. Sometimes there are seeds. So, there is this mat.

Sometimes seeds have to be planted. So now the rooftop plants need to be strong and need less food than the ground plants. So we must not use plants, which are voracious eaters and require high maintenance. They cool the air by releasing vapor, and the shade helps too. It is different from picking ground plants because the roof has its own conditions pertaining to the sun and the wind. Sometimes instead of a separate medium, there are these circular bags or tubes that are filled with a growing medium, and plants or seeds grow on this.

So, these are better for waterproofing purposes and things like that because the soil is not in direct contact with the roof. So, using green roofs in cities or other built environments with limited vegetation can moderate the heat island effect, particularly during the day. Green roof temperatures can be 4 degrees lower than those of conventional roofs, and this can reduce the city-wide ambient temperature by even up to 3 degrees centigrade. In addition, green roofs can reduce building energy use by 1% compared to conventional roofs, reducing the peak electricity demand and leading to an annual savings. A roof that does not have a green cover will be subjected to intense solar radiation, which will get either absorbed or reflected back.

When it rains, the stormwater runs off from the terrace of the building. Whereas when we have a green roof, there is less transmission or conduction of heat, and also there is very little reflectance of heat. Besides, there is increased biodiversity, and when it rains, the rainwater is retained when you have a green roof. Let us look at green roofs in summer and green roofs in winter. So, green roofs are energy efficient, as reducing the heat flux through the roof and using less energy for cooling or heating can lead to significant cost savings.

In summer, the green roof protects the building from direct solar heat. It helps in temperature regulation by providing a cooling effect by reducing the urban heat island effect and by storm water management. In winter, it conserves heat gain from solar

radiation, which in turn gets re-radiated to the internal space at night after a time lag. In winter, the green roof minimizes heat loss through added insulation on the roof, through insulation, snow management, extended lifespan, and it improves the air quality. Energy conservation translates into fewer greenhouse gases.

The temperature of waterproofing membranes under green roofs, based on a study, has shown that the membrane temperature beneath the green roof is lower than that of the membrane that is exposed. In winter or summer, when the mean temperature is 0 degrees centigrade, the temperature under the membrane of a conventional roof is 0.2 degrees centigrade, and the temperature under the membrane of a green roof is 4.7 degrees centigrade. Whereas, when the mean temperature in summer is 18.

4 degrees centigrade, the temperature under the membrane of a conventional roof is 32 degrees centigrade, and the temperature under the membrane of a green roof is 17.1 degrees centigrade. Let us now look at case studies. The first case study is in Hyderabad. We will look at the CII Saurabhji Godrej Green Business Centre.

This building is located in Hyderabad on a site area of 4.5 acres with a built-up area of 20,000 square feet by architect Karan Grover. It's a commercial office building that is LEED Platinum rated. It is an environment-friendly building as it efficiently uses the natural resources, reduces pollution in its surroundings, and generates minimal waste compared to any other regular benchmark building. The building is economical by using local materials, which cut down the transportation rate and also make it more affordable.

energy saving by using more daylight into the building and utilizing electricity efficiently. Let us now look at the green component of the building. Green elements of the CII Saurabhji Godrej building include solar PV panels and a wind tower, which is a prominent element used to cool the inside building and to improve indoor air quality. On the roof garden, there are more than 600 floras that were replaced during excavation. More than 600 floras were replaced during excavation, and all those are native trees and the ones that are capable of adapting themselves to the local climatic conditions.

One important feature that is of interest to us is the roof gardens. They have followed the traditional technique of rainwater harvesting, and 60% of the materials used in this building are recycled. Let us look at the green roof. 55% of this building's green roof is covered by extensive green roof. First, the advantage of using this green roof is heat absorption.

So, green roofs minimize heat absorption, reducing the transfer of heat into the building by covering a significant portion of the roof. Second is preventing heat islands. Roof gardens prevent heat islands on the roof and act as insulation against solar heat ingress.

Third is rainwater harvesting. Green roofs contribute to rainwater harvesting, helping to manage water sustainability.

Fourth is preventing seepage. Systems preventing seepage into the ground are installed in pedestrian areas and parking lots. Fifth is division of parapets. Green roofs on curved walls are divided into parcels separated by parapets. Sixth is build-up layers. On concrete roofs, the green roof system starts with three waterproofing layers followed by sandy soil, pervious paver blocks, and a grass sod.

Seventh is water conservation. The building achieves a significant reduction in municipally supplied potable water through the use of low-flush toilets. Recycled water from the building is used for irrigation and watering the plants. During dry seasons, the green roofs are irrigated daily through this recycled water. All waste water from the building undergoes root zone treatment, which we have already seen in one of the previous classes using specially selected plants to purify water for irrigation and other uses. We will now see another case study, which is the Nanyang Technological University in Singapore.

It has a built-up area of 10,000 square meters, designed by CPG Consultants Private Limited. It is an educational building in a tropical climate. Malaysian buildings receive high solar radiation mainly in the west and east facades in the afternoon. The sloping green roof has helped to minimize the west openings and shade the rest of the building. On top of the two curves that interlock with each other is a very dense grass turf, which forms a green roof.

Apart from the way it looks, which is extremely aesthetically appealing, the green roof helps to absorb the intense solar radiation, and therefore it reduces the thermal heat gain inside the building. It is more or less like a natural insulation. Rainwater is harvested, and it aids in cooling the surrounding air. The lush roofs offer outdoor gathering spaces for the users because they are accessible by stairs along the edges or directly at some points from where the roof rises from the ground. This integration of the green roof as an active functional area shows that the type of nonlinear thinking that normally designers use is not necessarily the best way to design.

Let us look at the sustainable facade feature. This is a four-story building. The four-story building with its eye-catching sloped grass roof was designed to blend with the NTU's garden campus setting. Apart from being aesthetically pleasing, the green roof doubles as a scenic outdoor community space where teachers, students, and everybody else interact. The green roofs keep the ambient temperature low and reduce the heat during the daytime.

The green roof also reduces water runoff from heavy rain. The growing media of the green,

which are the volcanic rocks and sand together with the turf grass, can hold water, and the water will go into rainwater harvesting to reuse it. The roofs create open spaces and insulation for the building, cooling the surrounding air. Planted grasses are mixed with the native species to colonize the building and bond it into the setting. The green roof has a drainage system.

As such, let us look at the other advantages of green roofs in NTU. This green roof makes the building energy efficient. The green roof can lower the rate of heat energy transfer from the roof and also lower the amount of energy required for cooling, which actually translates into greater cost savings. Energy efficiency without a green roof. During the day, the green roof protects the building from direct solar heat, and during the night, the green roof reduces the loss of heat energy due to the thick layers.

Next is facade orientation. The building is specifically oriented, facing the north and the south. This is to minimize the solar gain and heat load in the morning. The glass exterior facade permits natural views and sunlight into the building, which allows visual exchange between indoor and outdoor spaces. The swirling green roof is the most iconic sustainable feature of this campus. It starts from the ground and extends the feel up on the roof to the building, reinforcing the concept of the green continuum.

According to NTU, verdant turfed roof blends with the lush greenery and environment. The turf landscape acts as a scenic outdoor communal space. The green roof helps in lowering the roof temperature as well as ambient temperature, and therefore it reduces heat gain to the air-conditioned building. The building's orientation is with its facade facing north and south, and that also minimizes solar gain. High-efficiency discharge lights are adopted throughout the building.

The rainwater collection system is fitted on the green roof for irrigation. The rain sensors are installed on the green roof to automate the irrigation process, whereby irrigation is ceased when it rains. The curved building is embracing a courtyard with water features and plants. The reflection of the trees and nature can be seen on the all-glass exterior. So, today we have seen an advanced passive strategy called green roof, which is nothing but having vegetation on the roof. But this process has to be pre-designed because there is an addition load to the structure.

Also, insulation of the roof becomes important; insulation from moisture as well as heat becomes important. We saw the advantages and disadvantages of the green roof, and we saw two case studies where green roofs have been used to effectively lower the indoor temperature. With this, we will stop today's class, and we will continue with the next class, in which we will learn another advanced passive strategy. Thank you.