

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

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**Lecture 02**

Roof

Pond

System

Hello, dear students. We are here to see yet another advanced passive system. Today we will see a system called the roof pond system. A roof pond system is a passive technique that uses water stored in a pond located on the roof of a building to lower the indoor temperature through the process of evaporation. This system can be an effective and energy-efficient way to cool buildings, especially in hot and dry climates where the diurnal variations are very high. A roof pond is a passive cooling strategy, and it is based on the increased heat power of inexpensive and widely available water.

In general, during the day, the pond is covered to prevent heating and open for cooling at night. The heating cycle will be reversed in winter. Among different elements of the building envelope, the roof is believed to be the most important when it comes to developing passive measures. This is because this is the building envelope part that is most exposed to the outside, and therefore it is vulnerable to direct solar radiation.

There is a lot of research done that indicates that the roof alone is responsible for even up to 50% of the heat load in single- and two-story buildings during the summer. Shading the roof, increasing roof thickness, enhancing albedo of roof, insulating the roof and providing false ceiling or vegetation on the roof. Spraying and flowing water over the roof and provision of roof ponds are several passive measures for regulating heat gain through the roof. When we use water, it becomes an ideal thermal mass because of the large amount or volume of the water that is present. Water has a large volumetric heat capacity, is very cheap, and is non-toxic. Roof ponds can provide passive heating as well as cooling.

This is an invention by Mr. Harold Hay and his colleagues way back in the 1860s. Let us now see some of the components that are required for a roof pond, along with another brief introduction. So the purpose-built pond or water storage area of the roof is frequently made up of waterproof materials. So in order to have a roof pond, you need to have proper and adequate waterproofing done.

So, if this is the roof structure, there has to be an adequate waterproof membrane. You need pond liners that preserve the integrity of the roof structure and stop water seepage. So, the pond liners become another important component. Also, vents on the inside of the building that are positioned to facilitate air movement and the exchange of cooled air are known as inlet and outlet vents. These are not mandatory, but this can be there.

So the presence of an insulating sheet, which is embedded or floating insulation, or it's a floating fabric. It can be varied, but it is mandatory to be there. So, roof ponds can be built cheaply by enclosing water with rigid transparent plastic covers in plastic bags, metal, or fiberglass tanks. So, we can also have plastic bags filled with water and laid on the roof.

These can also aid or function as a roof pond, and they act as a double protection against any seepage. And passive cooling has also been shown to provide excellent thermal comfort and consistency of indoor air along with very low energy consumption. We look at the working principle. A roof pond is a passive cooling method that relies on the higher heat capacity of readily available, inexpensive water. The pond is typically covered during the day to keep it from heating up, and it is opened at night to cool it down.

Roof ponds can be as simple as enclosing water in a fiberglass tank with hard transparent plastic covers, or they can be as complex as metal or plastic bags. There are broadly two types of roof ponds. One is an uncovered roof pond, and another is a covered roof pond. Further, under an uncovered roof pond, we can have an open roof pond without sprays and an open roof pond with sprays. Under an uncovered roof pond with and without sprays, the roof pond is not covered, but it is left open to the sky.

One of the variants is to have water spraying all along. It doubles up in two ways. When we have an uncovered roof pond without spray, we are left to the mercy of the water body to warm itself or cool itself in order to control the indoor temperature. But when we have a spray attached to it, what happens is that not only does the water on the roof aid in cooling the building, but then when there is new water sprayed, there is the addition of cooler water in the already existing warm water. So, the pace at which the indoor comfort or indoor temperature reduces gets enhanced.

The second category is a covered roof pond with sprays. So, under this, what happens is this roof pond has a cover. So, there is a roof pond, and there is water here, and this roof pond has a cover that is movable, which is slidable. So, if this is water, this cover, this is what I call the cover. One can slide this cover over this, and this can also be slid behind, leaving the tank exposed to the night sky for cooling.

So, the night sky cooling happens at night. So, and this is during the day. Once the water gets cooled at night, then this is slid back in position during the day because of which cool water is actually trapped inside here, and that helps to make the indoors cooler during the day. That keeps the indoors cool during the day. So this is the basic principle.

Again, in this we can have two types. One is with spray, and another is without spray, as shown here. So, the sprays can function along with the stagnant water body. So, what happens during the summer? During summer, we need the indoors to be cool. So, what happens is that during the day, the roof pond is closed.

Solar radiation strikes and is reflected back. The water body is there because, because of this water body, the indoor gets cooled during the day. At night one has to slide the cover open, due to which the water body gets cooled due to the nocturnal cooling of the night sky, which is the biggest cooling sink. This water gets cooled at night in the summer, and during the day, it is slid back into position. This gets slid back during the day, and this is what causes cooling during a summer day inside the rooms.

What happens during winter? During winter, we would want the indoors to be warmer. So, during the daytime in winter, the cover is slid open so that solar radiation strikes on the body, and the body becomes warm due to daytime exposure to the sun. Now the water gets warmed, and during the night the cover is slid back, and what happens is the warm water radiates warmth inside the room, which is actually cool during the winter. So, the room becomes warm and comfortable during winter nights. So, the cool roof or the roof pond is used effectively during summer and winter to control the indoor temperature.

Let us now look at the design considerations. First is climate. One needs to understand whether this passive system is adaptable to the climate under question. So, adaptability to different climates and effectiveness in specific temperature and humidity ranges must be verified.

Second is the pond size. One needs to determine by factors such as building size, the location, the climate conditions and the cooling needs of the space whether the pond size is sufficient. The third is materials. Selection of appropriate materials for pond construction is important to ensure durability and water retention. Then fourth is energy efficiency. It is important to understand it.

Next are the results and the benefits of using a roof pond. The first is energy efficiency. By using a roof pond, a lot of energy can be saved, and this reduces the need for mechanical cooling systems, resulting in energy efficiency. Second is cost effectiveness. Compared to traditional cooling and air conditioning systems, a roof pond system can be more cost-

effective to implement and maintain.

The third is the sustainability aspect. This aligns with sustainable architecture principles reducing the carbon footprint of buildings. Fourth is provision for comfortable indoor environment. Despite the hot and humid climate, occupants have experienced a more comfortable indoor environment due to the passive cooling provided by the roof pond. Let us now look at the advantages.

These systems have proved to be useful in hot, dry, and temperate climates. Some variants are also applicable in humid climates, but they have been proven to be very useful in hot, dry, arid, and temperate climates. A roof pond can also provide co-benefits in terms of storm water management, and the stored water can be useful for some other purposes too. In case of an emergency, it can double up as a fire extinguishing purpose. The performance of a roof pond is not dominated or is not impacted by the orientation of the building, unlike many other passive systems that have a direct connection to the orientation of the building.

Again, the roof-bound cooling system does not in any way come or tamper in the way of the indoor humidity due to the presence of water because the humidity or the water is not directly related to the habitable spaces, but it is physically apart. So, that way, the direct evaporative cooling system does not bear anything on the indoor humidity. Let us now look at the limitations of the roof pond system. Roof ponds increase the dead weight. The dead load of the building gets increased because of a roof pond, and water is actually a very heavy element.

So, this system is not suitable in buildings that are not pre-designed for roof ponds, and they are definitely not suitable in structures that are lightweight. So, these systems are not suitable in buildings that need retrofitting. So, pre-existing buildings So, pre-existing buildings are not suitable; new buildings designed to take up the extra load of the water works for this system. Roof pond systems can be installed on top of flat roof surfaces only.

So, we cannot use it on sloped roof. Roof ponds, because of the presence of a large amount of water, can hinder accessibility. So, they can be inaccessible to the roof. So, these are the major drawbacks. Next we will see the variants of roof pond. So a roof pond is basically a principle, and there are many variations of a roof pond.

First is the uncovered pond without sprays. Second is an uncovered roof pond with sprays. Third is the covered roof pond with sprays. And fourth is the covered roof pond without sprays. The skytherm with its insulation is another variant.

Energy roof, which is a hybrid system, is another variant of the roof pond. Then we have

cool roofs. Walkable ponds. Sometimes the roof pond can also be designed by incorporating the provision or facility to make it accessible.

So, these are called walkable ponds. Using wet gunnies in over the roof ponds. Then the next variant is a cool pool. A shaded pond. and a ventilated roof pond. These are all the various other options or variants of a roof pond.

If we look at the comparison of various characteristics, the uncovered roof pond with spray is relatively highly effective, and it has low initial costs. It is easy to construct and it has widespread know-how. Its application in an uninsulated concrete roof is possible. Uncovered roof ponds without sprays have low initial costs, have very little maintenance, have less water consumption, do not need mechanical operation, do not call for daily attention, are easy to construct, have widespread know-how, and their application is in an uninsulated concrete roof. If we look at covered roof ponds with spray, they have relatively high effectiveness.

They have a low initial cost. They are easy to construct. There is widespread know-how, and there is application in uninsulated concrete roofs. Whereas the covered roof pond without sprays has a low initial cost, has no maintenance and function costs, is easy to construct, has widespread know-how, has application in an uninsulated concrete roof, and can function in winter too. The skytherm, on the other hand, has relatively high effectiveness, has a low initial cost, has very little maintenance and function cost, is easy to construct, has widespread know-how, and also functions during winter. The energy roof has low contamination and fixed water protection.

It has application on a tiled roof and has embodied a building form. The cool roof, on the other hand, has relatively high effectiveness, has low contamination with fixed water protection, and has application in uninsulated concrete roofs. The walkable pond has low maintenance and function costs, has low water consumption, has low contamination, does not need mechanical operation, does not have demand for everyday attention, and has application in an uninsulated concrete roof. The wet gunny bags are by far the most advantageous. It's relatively high effectiveness, low initial cost, very little maintenance, low water consumption, low contamination, and does not need daily attention.

It's easy to construct. It has applications on uninsulated concrete roofs. Whereas a cool pool has low water consumption, has absence of daily demand attention, and has application in an uninsulated concrete roof. It is embodied in building form. It is cooling more than one floor and has winter function. The shaded pond again has more advantages than many of the other systems.

It has a low initial cost. It has null maintenance and function costs. It has low water consumption. It has low contamination because it has fixed water protection. There is absence of mechanical operation, absence of demand for daily attention, easy to construct. can be applied on uninsulated concrete, has application on tiled roofs, embodied to building form, and cools more than one floor in winter.

The shaded pond has low initial cost Null maintenance and function cost, low water consumption, low contamination, absence of mechanical operation, absence of demand for daily attention. It also is easy to construct and has widespread know-how, whereas the ventilated pond has a zero maintenance and function cost, has low water consumption, has low contamination, has an absence of mechanical operation, and has an absence of demand for daily attention. Its application is on uninsulated concrete, has walkability of roof, can be applied on tiled roof, and has winter function. So, these are the variants along with their characteristics. We will quickly see a small case study that was done on a prototype called the Phoenix prototype test structure.

So, this is a 10 feet by 12 feet room, and aggregate lightweight concrete block walls were used with the external one and a half inch rigid polyurethane insulation on the east and west walls. The external insulation on north and south foundations and a 4 inch thick floor slab with a 4 feet by 8 feet panel of one and a half inch thick polyurethane movable insulation were used. On the south side, an overhang carport for a movable rooftop was used, and a 12 feet by 2 feet window on the north and south walls was the entry door. On the south wall, it was about 6 inches to 7 inches thick water-filled bags, which were supported on 26-gauge steel sheets. The study showed that when the outdoor temperature swung between 85 degrees Fahrenheit and 55 degrees Fahrenheit,.

The indoor dry bulb temperature at 5 feet height remained fairly constant, and it was also sinking very well with the water temperature. So, on a prototype, on a scaled model prototype, the roof pond worked very well. Another small study was done that discussed the cooling enhancement using acacia gum-based hydrogel in roof ponds instead of water. This was done at Vishvesh Raya Technology University. And this talks mainly about the use of acacia gum hydrogel in roof ponds for evaporative cooling for energy efficiency.

So, the comparison was between bare aluminum roof sheet, roof pond with water, and roof pond containing acacia gum-based hydrogel. The first set of experiments were carried out, and the result showed that the experiments involved daily watering of the roof pond in the model rooms with different roof components like bare aluminum sheet, a roof pond with water, and a roof pond containing acacia gum-based gel. And the observation showed that on the next consecutive day after watering, there was a significant drop in room air temperature by around 2 degrees to 4 degrees in the model rooms with roof ponds

containing water and the aqua gel compared to the room with a bare aluminum roof sheet. The hydrogel was observed to resist evaporation and retain water, providing a cooling effect on the next consecutive day. The hydrogel-based roof was found to be reusable for several days without any biodegradation.

In the second set of experiments that was conducted, the roof ponds were maintained dry for 3 consecutive days. The experiments demonstrated that the dry acacia gum-based hydrogel, which I will call just hydrogel, over the roof was still found to result in lowering the room air temperature from 6 pm to 6 am by about 1 and a half degrees as compared to the control case. The reduction in room air temperature was also observed in the case of a dry roof pond without the hydrogel, but was next to the hydrogel case by around 1 degree centigrade. The experiments also showed that the heat transfer from the edges of the dry roof pond can be significant, causing a drop in average room air temperature between 6 pm and 6 am.

So, this experiment showed the efficacy and effectiveness of the roof pond. So, with this, I stop this class on roof ponds, and we will continue with another class, another advanced passive strategy in the next class.