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

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Lecture 02

Case studies - Hot-dry climate

Hello everyone. So in our last class, we saw the strategies that have to be adopted in hot and dry climates. The simple passive strategies as well as advanced passive strategies are given out by the Mahoney's table as well as by climate consultants. Today we will look at the case study of hot and dry climate buildings where passive strategies have been employed. So today we will look at these three case studies.

The Pearl Academy of Fashion, the Torrent Research Center at Ahmedabad, Gujarat, and the Lycee Charles de Gaulle, Damascus, Syria.

Now the Pearl Academy of Fashion is located in Jaipur, Rajasthan. It's an educational building designed by Morphogenesis. The site extent is about 3 acres with a built-up area of 11,745 square meters. The climate type is hot and dry.

This institute is located around 20 kilometers from the city of Kukas, which is an industrial district and is pretty much considered to be a soulless city on the outskirts of Jaipur. It's a hot, dry desert atmosphere. Controlling its microclimate inside the project is difficult because of the highly unfavorable climate. That is why a variety of passive climate control techniques is important in a building typology like this. This will reduce the reliance on energy-intensive mechanical environmental controls such as air conditioning.

This academy's design had to combine contemporary updates of traditional Indo-Islamic architectural features with passive cooling techniques, which are common in Rajasthan's hot and dry desert. These include elements like open courtyards, water features, stepped wells or baolis, and jaalis, which are perforated stone screens. All of these components have their roots in historical buildings. But in this building, these elements are also translated into contemporary forms and have been used. If you look at the objectives, the goal of this building was to design a low-cost, climate-responsive campus. Traditional and vernacular materials were used in this campus.

Passive cooling strategies, which are prevalent in the hot, dry climate of Rajasthan, had to be used. The fourth objective was to create highly interactive, thermally comfortable, and naturally ventilated spaces. This building uses a double skin. It is drawn from the traditional jaali construction element, which is very common in Rajasthani architecture because it shields the structure from the elements. The building's double skin serves as a thermal barrier between the building and the outside.

Based on the orientation of the facade, computational shadow analysis has been done to understand the density of the perforation of the outer skin. Through windows or fenestrations, the outer skin, which is a jali, is kept 4 feet away from the building. This reduces the direct heat gain inside the building. The temperature of the incident wind is lowered by passive downdraft evaporative cooling.

Which is made possible by drip channels that run around the inner face of the Jali. The basement, which is derived from the Baoli or the stepped wells, is again very popular and famous in this part of the world. The Baolis or the stepped wells are water bodies that are subsurface. And in the basement, these are used. Also, earth sheltering, thermal banking, which is nothing but using the thermal mass and evaporative cooling, has been used to modulate the surrounding temperature.

Basically, the zoning comprises a subsurface area, which is a student's area. And the first floor comprises an administrative block and classrooms. The second floor is completely the students' area, and the third floor is a formal zone. In this picture, you can see the outer Jaali and the inner facade, the inner wall. Both together comprise a double-skin facade.

Public interaction spaces are present along the water body, which is derived from the Baoli, to keep it cool throughout the day. The classrooms are close to the library and auditorium for convenience in activities. The structure is dependent on the stack effect evaporative cooling system as the primary passive design strategy to make it energy efficient. Also, to ensure proper circulation in all the spaces which have comfortable temperatures, many techniques have been used. Time lag is another technique with the help of thermal mass that is used in this building.

So the zoning comprises a performance area like a ramp, a library with its spill out spaces, an open exhibition area, and a spill out zone for the canteen. This design makes use of self-shading silver coats to regulate interior space temperature and also open stepped wells while maintaining enough natural light in studios and classrooms. The entire structure is elevated above the ground, and a naturally occurring thermal sink is created by a scooped-out belly that is cooled by evaporative cooling water bodies. This underbelly which is thermally banked on all sides, forms the project's anchor and functions as a sizable area for student exhibitions and relaxation.

This floor gradually transfers heat to the surroundings throughout the night as the desert's temperature gets reduced. By using passive principles, it is seen that 30% of the site is covered by landscape or plants. 80% of the operational hours are served by natural ventilation. 5% of the site is covered by water.

50% of the spaces use active cooling. 100% of the spaces are designed for natural ventilation. And all the materials, 100% of the materials, are sourced locally. For about 20% of operating hours, 50% active cooling happens. Let us look at the passive design strategies that are used in this building.

1. First is form optimization and orientation. The curvilinear geometry is generated through a computerized shadow analysis that tracks the precise movement of the sun through the day and across the seasons. The form of the building is a perfect rectangle. The two stories of the classroom studios and offices are on the Pilatus above the void. The basement serves as a large recreation and exhibition area and houses the cafeteria and spill area for the students.

The first and second floors are clad in printed panels attached to a metal frame. The ground level is partially sunk to segregate access, which helps to protect it from heat. Open and glass-walled walkways surround these undulating blocks, which define openings to the lower level. Now you can see the self-shading silver coats are used to control the temperature and allow for sufficient daylighting inside the built spaces. The double-skin facade protects the building from the harsh outdoor environment.

The outer skin is a jaali, and it sits at about 4 feet, which is 1.2 meters away from the main facade of the building. So the space between the jali and the main structure acts as a buffer zone. And also, the jaali, as shown here, acts as a double skin. The outer skin is the traditional Rajasthani jaali, which sits at a distance of 1.2 meters from the main facade. Additionally, the jaali allows diffused light to come in as well as reduces direct heat gain.

So, this Jaali serves the dual purpose of filtering light as well as providing privacy. When the diffused light comes in, it lights up the studios and classrooms. Also, it reduces the direct heat gain and controls the temperature of the spaces inside.

2. Second is ventilation and daylighting. Now, the open-to-sky central courtyard helps in cross ventilation.

Stack ventilation and evaporative cooling techniques have been used. The courtyard permits indirect sunlight into classrooms, creating naturally ventilated and well-lit single-loaded corridors. It is also in a single bay, which is naturally lit. Daylight illuminates 90% of the gross floor area. The building campus is constructed on a 9-meter grid.

It is also a single bay, naturally lit, and cross-ventilated campus, and this grid configuration allows for daylighting, ventilation, and a flexible partitioning system for years to come. Daylight illuminates 90% of the gross floor area. Earthen pots are used for thermal insulation. Earthen pots or matkas of 35 cm diameter are sourced from local potters and placed on a flat roof chhaja at a distance of 2.5 cm in between. The gap between the pots is filled with sand and

Broken bricks are covered with a thin layer of concrete. The filling and the air in the pots act as insulation for the entire structure.

3. The next technique that is used is evaporative cooling. A natural thermal sink is created by raising the building above the ground. The ground is scooped out up to 4 meters and filled with recycled water from the on-site sewage treatment plant. The basement becomes a microclimate generator, and the stepwell section cools the building from within as well as the air coming inside. The workspaces and the courtyards cool to 26 degrees Celsius when it is 47 degrees outside. The water body is 610 square meters and it cools about 11,745 square meters of built-up area. The air is sucked in from around the buildings as the building is elevated.

The air is released through the open courtyards. The stepped well lowers the temperature of the air. Then we look at the materials. Here, the materials used for construction are a mix of local stone, steel, glass, and concrete, keeping in mind the climatic needs of the region while retaining progressive design intent.

4. Energy efficiency is of primary importance, and this institute has 100% self-sufficiency in terms of captive power.

30% of the total site area is used for landscaping, and the water body is fed by recycled water from the sewage plant.

5. If you look at the materials that have been used, the materials come from Rajasthan, and Jaisalmer stone, Kota stone, granite, and slate are quarried from within Rajasthan. Aluminum and concrete come from Jaipur city limits. And stone, glass, and concrete, as well as the matkas from local craftsmen, come from within a distance of 300 kilometers. Also, the concrete jaalis are cast on-site in Jaipur.

6. Then, we move on to landscaping. 30% of the total site area is used for landscaping. The water body is fed by recycled water from the sewage treatment plant. The water body, as well as the green spaces, are mostly in the shaded zone. This lowers the evaporation of water and aids in evaporative cooling.

During the night, when the temperature of the desert drops, the floor slowly dissipates heat to the surroundings and creates a thermally comfortable environment. Rainwater harvesting, as well as wastewater recycling through the sewage treatment plants, takes place.

7. Now, the passive design strategies limit the use of air conditioning in spaces by up to 50% of the total area by creating an on-site microclimate that reduces cooling demand. Further, out of this 50% of air-conditioned spaces, the active air conditioning is used for less than 25% of the occupancy hours. 22% of the surface area of the site is covered by plants, and 4% of the surface area of the site is covered in water, which together works to create a microclimate conducive to the site.

Air conditioning is only used for 25% of the occupancy hours. So, if you see, this graph shows the comparison of the energy consumption of this building with respect to the Griha benchmark. According to Griha, the combination of AC and non-AC consumption versus the AC and non-AC consumption as given by Morphogenesis is similar. Lower by at least one-third. The next case study which we will see is the Torrent Research Center.

Let us now look at the case study of Lycee Charles de Gaulle in Damascus, Syria by Atleus Lyon Associates. It has a built-up area of 5,600 square meters, completed in the year 2006. And it lies in the hot arid climate. Now, if you look at the site context, this houses almost 900 students in a garden-like school with classrooms integrated into the system of courtyards and green patios. Alternating spaces, masses, gardens, and a dramatic skyline rendered by the distinct vertical elements of the proposed solar chimney make this building highly popular.

The school is mainly surrounded by residential blocks on the east and south sides and a hospital on the north. Along the west, it merges smoothly into the topography of the Mesa hills. The warm average maximum high temperature is 37 degrees centigrade in August. The coolest average minimum low temperature is 2 degrees centigrade in January. Damascus receives an average of 234 mm of precipitation annually.

Mean relative humidity for the average year is recorded as 50%, and on a monthly basis, it ranges from 36% in June and July, making it extremely hot and dry, to 72% in December and January. The hours of sunshine range between 5.7 hours per day in January to up to 14 hours in July. There are 3,634 sunshine hours annually and approximately 10 sunlight hours each day. Now, let us look at the design. When we look at the site plan, in order to conserve water for landscaping, a pond is built in the lowest part of the site below the gymnasium to drain rainwater from the site and from the roofs of the building.

To establish the necessary microclimate, all the existing trees have been maintained on the site. New trees have been added on-site where species adapt to the climate, are easy to grow, and do not require much water or maintenance. Shading and cooling of the classroom roofs to reduce solar heat gain inside the classrooms become important. Wind-assisted solar chimneys are used to drive cross-ventilation throughout the classrooms. The strategies that are used are as shown here.

The winter strategy uses the sun. The sun heats the patios and the solar chimneys, accelerating the flow of air through the thermosiphon effect. So, winter draws in preheated patio air to the passage of the floor slab and then heats the hollow bricks for external surfaces. The chimneys are faced with a polycarbonate sheet to trap solar radiation and enhance the stack effect. So here we have the solar chimneys, which are used for the stack effect.

The shading device above the courtyards provides solar protection during summer days and is open for cooling at night by radiation to the sky. In winter, the operation is reversed to capture solar gains and prevent their loss to the clear sky. So summer strategies include sun visors, ventilation, and courtyard microclimate. So the microclimate is provided by the sun visors and the vegetation that regulates the temperature and humidity due to its natural transpiration. Double block walls are used along with courtyards and a cloth shed which covers the courtyard during the harsh season.

On a summer day here, it demonstrates how the solar chimney functions. Now the slabs are cooled due to contact with the earth, which in turn cools the pipe. So the earth cools these pipes which are below the slab, and because of this, air enters the pipe. Air enters the pipe and gets cooled because of the contact with the earth.

This cooled air finds its way through outlets at floor level. It gets warm and flows through the outlets placed at a higher level through the chimney. Cool air enters and leaves through the chimney and escapes out. So the hot air escapes out from the solar chimney by creating an upward draft. So the outdoor intake air, which comes either directly from the shaded microclimate of the courtyards or is pre-cooled using miniature earth ducts made up of pipes embedded in the ground floor slab.

Operable lures at the air intake and exhaust provide ventilation control. The thermal mass of the chimney releases heat stored during the day and continues to draw air through the open windows and the earth ducts. Cool night air flushes the classrooms, cooling down the thermal mass and providing comfort for the next day. Single and double unit solar chimneys have been used in this project. A single unit is approximately 175 centimeters by 60 centimeters.

In this picture, you can see how the solar chimneys are placed all along the buildings. During winter, we have seen that the temperature can drop even up to 2 degrees centigrade. The cool air from the courtyard enters the building and gets warm because of the contact of the tubes with the earth. Something like an earth air tunnel, and this warm air rises and enters the building. It becomes further warmed and escapes through the solar chimney.

So, a combination of solar chimney with the concept of earth air tunnels, earth air heating creates a warm environment inside during winter and a cool environment inside during the summer season. So, alternating patios and classrooms. These patios act as microclimates for two classrooms placed one above the other. Retractable shades are placed over the courtyard, which cover this courtyard during the hottest part of the year and can be removed during the cooler part. Wind-assisted solar chimneys

These know the sun heats the air with a chimney which rises up, creating an updraft, sucking air from the PVC pipes running under the floor slabs. The high school looks over the hill. To the right is the primary school. This one and to the left is the high school. The exterior walls are made up of 20-centimeter hollow blocks.

Separated by an air gap of 5 centimeters and an interior wall which is made up of 10-centimeter concrete blocks. So, the exterior is a 20-centimeter hollow block, then it has an air gap of 5 centimeters which acts more like insulation, and then there is a 10-centimeter solid concrete block. These walls give out coolness stored during the night as a result of ventilation. The 25-centimeter air gap between the roof helps in air circulation.

The solar chimneys are laid out in such a way as to provide natural ventilation from the cool air in the patio, and this cools the premises as it passes through the slab of the ground floor. So, wind-assisted solar chimneys have been used, and then there is a 25-centimeter air gap between the roofs. So, shaded and landscaped courtyard spaces around the classrooms create a walkable outdoor microclimate, connecting the classrooms and serving as the environment for social interaction between the students. So, in today's class, we saw two case studies. One is an Indian case study near Jaipur, and another is in Damascus.

Both are classified as hot and dry areas, and we saw how both these places have used all the simple and passive strategies to make the indoors cool and be less dependent on active ventilation. With this, we stop today's class and will continue the next class by discussing the passive strategies in composite climates. Thank you.