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 03

Passive Design Strategies for Composite climate and Case studies

Hello everyone. Welcome to the class on bioclimatic architecture, future-proofing with simple and advanced passive strategies. Today we will have a look at the passive strategies that must be adopted in composite climates. First, we will start with understanding what the Mahoney's table says about the design and planning considerations for composite climates.

According to Mahoney's table, the planning should be compact courtyard planning. Then, it should have a compact layout of the estates. The rooms should be double-banked with temporary provision for air movement. And most of the time, air movement is not a requirement. Openings should be medium.

There should be heavy external as well as internal walls. The roof should be heavy with a time lag of 8 hours. There must be space for outdoor sleeping required. So this is what Mahoney's table says. Now, let us see how to use Climate Consultant for a composite climate to arrive at appropriate design strategies, passive strategies, as well as active strategies.

So, we will see for New Delhi, which is representative of a composite climate, For the month of March, what are the best strategies? By itself, 47.3% of the hours are comfortable in this place for this climate type. Sun shading of windows will make this place comfortable by 29.6% for the month of March. So, there are 31 days in March.

31 multiplied by 24 is 744 hours for the month of March. Out of which, 220 hours will become comfortable with solar shading of windows. High thermal mass with night flushing will make 172 hours comfortable. Then, we can adapt comfort ventilation, which will make 32.4% of the hours shift from uncomfortable to comfortable. Then, internal heat gain will shift the comfort hours by 22%.

And passive solar direct gain high mass will shift 16.1% of the hours, or 120 hours, to a comfortable range from an uncomfortable range. So, because of just passive strategies, 98% of the hours for the month of March can become comfortable. By following simple and active passive strategies. Now, in order to make all 100% of the hours comfortable, what should we do? So, there are these three strategies, which are active strategies, and the remaining are passive strategies.

So these active strategies would include dehumidification of air, which will shift 5.5% of the hours to become 41% of the hours comfortable. 0.4% of the month, or three hours, can be made comfortable with cooling and dehumidification. Whereas one hour will be made uncomfortable by heating and humidification if needed. So these are the three active strategies to ensure that 100% of the hours become comfortable. Then how can this be done for the month of March?

A whole house fan or natural ventilation can store nighttime cooling in high-mass interior surfaces, and using the concept of night flushing, we can reduce or eliminate the air conditioning load. Then this is one of the more comfortable months, so shade to prevent overheating, open to breezes. We can prevent solar gain or we can have solar gain as per our requirement. Good natural ventilation can reduce or eliminate air conditioning in warm weather if windows are well shaded and oriented to prevailing breeze directions. Also, we should shade the western facade by means of shading devices.

Or vegetation. Both of these will help to shade the walls, especially the western wall, through which maximum solar radiation may enter. On hot days, a ceiling fan can be used, which can reduce the temperature by 2.8 degrees centigrade. And therefore, less air conditioning is needed. The best high-mass wall uses exterior insulation and exposes the mass on the interior, or we can add plaster or direct-contact drywall.

Let us see for the month of June in New Delhi. Which is representative of a composite climate. What happens if we use only passive strategies? Now, 0.7 hours of the month are comfortable by itself, which is 5 hours. Solar shading of windows can make 36.9 hours or 266 hours become comfortable.

High mass night flushing is not an effective method. Whereas adaptive comfort ventilation can shift 4.6 hours or 33 hours into the comfortable zone from uncomfortable. So these are the only three effective passive strategies. Accounting for only 5% of the total month to be comfortable with the help of passive strategies. So in June, only 5% of the month will be effective with passive strategies.

So in order to make the other hours also comfortable for June, We have to use active strategies, and those active strategies are dehumidification, Which will cause 3.9 hours to shift to the comfort zone. So 29 hours will become comfortable, and 91% of the month will become comfortable with cooling and added dehumidification. That is 655 hours out of 720 hours need air conditioning for the month of June.

In New Delhi, which has a composite climate. So, what are these strategies that we can use for the month of June? What are these passive strategies and active strategies? So, use plant materials like bushes, trees, and ivy-covered walls, especially on the west, to minimize heat gain if summer rains support native plant growth.

The next strategy is to use window overhangs designed for this latitude or operable sunshades or awnings that extend in summer so that the wall does not have any solar radiation falling on it, or the wall is protected from solar radiation. So, protection from solar radiation is important. We can have double-pane, high-performance glazing on the west, north, and east but clear on the south for maximum passive solar gain. On hot days, ceiling fans or indoor air motion could probably reduce the indoor temperature by up to 2.8 degrees Celsius, and so you may need fewer hours of air conditioning.

But, in general, we have seen that you require air conditioning for the month of June without fail. Let us see what happens in the month of September for air. New Delhi's composite climate in the month of September means none of the hours are comfortable by themselves, whereas we can have sun shading of windows That can make 31.7% of the hours comfortable, or 228 hours to be comfortable. Adaptive comfort ventilation can make 50.8% of the month, or 366 hours, comfortable.

So, totally 50.8% of comfortable hours can be achieved by using these selected passive strategies. So, these are the passive strategies that can be applied to make the indoors comfortable for 41% of the hours. But In order to make the room 100% comfortable, you need to have active means, and the active means is dehumidification, which accounts for about 10% of the hours or 69 hours to shift from the uncomfortable to the comfortable zone. Then we have cooling and air conditioning.

Which is 47% of the hours or 339 hours that require air conditioning to make the indoors comfortable. So, these two strategies are needed in the month of September to make the indoors comfortable. So, what are these strategies that we must adopt for the month of September for a composite climate like New Delhi? We should have screened porches and patios that can provide passive comfort cooling by ventilation in warm weather and prevent insect problems. We must have good natural ventilation, which can reduce or eliminate air conditioning in warm weather if the windows are well shaded and oriented to catch the prevailing breeze.

We should use plant materials like bushes, trees, and ivy-covered walls, especially on the west, to minimize heat gain if summer rains support native plant growth. Also, shaded outdoor buffer zones such as porches, patios, and lanais oriented to the prevailing breezes can extend living and working areas in warm weather or humid climates. In order to produce stack ventilation, Even when wind speeds are low, we should maximize the vertical height between the air inlet and air outlet, like open store wells, two-story spaces, roof monitors, etc. Normally, this is a comfortable climate, so shade to prevent overheating, openness to breezes in summer, and using passive solar gain in winter will be very helpful.

Let us see what the strategies are to be used in the month of December in New Delhi, which is representative of a composite climate. In the month of December, 14.9% or 111 hours are comfortable by themselves. 1.2% or 9 hours can be made comfortable by solar shading of windows. Adaptive comfort ventilation can make the indoors comfortable by about 14% or 103 hours. Also, internal heat gain.

can make the indoors comfortable for 46.6% of the total hours or 347 hours out of 744 hours. 744 hours comes from 31 days in December multiplied by 24 hours, which is 744 hours. Then 38.4% or 286 hours out of 744 can make the indoors comfortable with passive solar direct gain high mass. So just by using passive techniques, you can have 81.7% of the hours or 608 hours out of 744 hours of the month to be comfortable by adopting only passive strategies. And the remaining 18% will still remain uncomfortable for the month of December unless you adopt some active strategy.

What is that active strategy? That active strategy is dehumidification, which can be applied for two hours of the month, then 18% or 134 hours can become comfortable if you use heating with added humidification.

So active techniques, which include heating and humidification, can make 18% become comfortable, making the total 100% of the month comfortable. So what are these strategies? Heat gain from light, people, and equipment will greatly reduce heating needs. So we should keep the home very tight and well insulated in December.

For the passive solar heating phase, most of the glass area on the south must be exposed to maximize winter sun exposure, but we should design overhangs to fully shade it in summer. We can use high-mass interior surfaces like slab floors, high-mass walls, and a stone fireplace to store winter passive heat and summer nighttime cooling. Sunny, wind-protected outdoor spaces can extend living areas in cool weather, such as enclosed patios, sunrooms, courtyards, or verandas. Trees must be either coniferous or deciduous, and they should not be planted in front of the wall. The front of the wall should always be exposed in such a way that solar radiation will fall on it and prevent the shadow of the trees from falling on the wall.

In order to prevent that, the trees should be planted beyond 45 degrees from the wall. Organize floor plans so winter sun penetrates into daytime, making the indoors warm. Now let us compare the various strategies and their impact for these various months. So comfort achieved using passive strategies: 98% of the March month can be made comfortable just with passive strategy.

Whereas for the month of June, 5% can be made comfortable with a passive strategy. In September, 51% of the month can be made comfortable with a passive strategy. Whereas in December, 82% of the month can become comfortable only with a passive strategy. What are these strategies? Adaptive thermal comfort ventilation can be used for the months of March and September.

It must not be used in the months of June and December. Whereas internal heat gain should be used only in the month of December. Sun shading of windows is a good strategy for March and September. Whereas adaptive comfort ventilation can be used only in June, and passive direct solar gain with high mass can be used only in December. In March, we can use high thermal mass night flushed, and this must not be used in June and September.

But adaptive comfort ventilation can be used for the month of December. Internal heat gain can be used in March, not in the month of June. In the month of December, this can be supported with sun shading of windows. Passive direct solar gain from high mass can be used in March as well as in December, but not for the months of June and September. So you can see for a composite climate, there are a variety of strategies strewn over the months.

It becomes very important for you as an architect to prioritize. Or have that strategy which can be operated in such a way that it can be used only for some months and need not be used for the other months. So you can even design some of these strategies yourself because composite is one of those slightly complex climates where you require all these strategies but in various months. In order to make the indoors 100% comfortable.

For the month of March, 2% has to be made comfortable, and that comes from humidification, cooling and dehumidification, heating and humidification if needed. Whereas cooling and dehumidification are needed for the months of June and September. But in December, heating and humidification are needed. For all three months, June, September, and December, dehumidification alone can also shift some hours from uncomfortable to comfortable hours.

This is how you understand the strategies that can be adopted for a composite climate. We will see how this is done in the further course of this lecture.

1. First is building orientation. You need to minimize the surface-to-volume ratio and minimize the perimeter-to-area ratio. You should increase compactness by reducing the surface area for the same volume, as we had already seen in the previous classes.
2. Second is how to use shading devices. So self-shading through massing results in cutting off a large amount of direct radiation. We had seen in the previous class, and also in much earlier classes, how self-shading can act as a strategy to reduce the impact of solar radiation. Understanding solar angles is important in designing shading devices.
3. Third is the use of shading devices. So horizontal shading devices are suited for southern exposure. Roof overhangs can also be easily used to shade the southern exposure on low-rise buildings. So this is perhaps the most economical and potentially aesthetically pleasing solution. Vertical shading is beneficial for the sides of the building that get direct sunlight during specific times of the day.

East-facing sides receive morning sun, and west-facing sides receive afternoon sun. Vertical shading elements such as vertical fins, screens, or vegetation can block sunlight. The lower angle sun reduces glare and still allows natural light to enter. Courtyards are another feature that can be used in this climate. So due to the incidence of radiation in a courtyard, the air gets warmer and rises.

Cool air from the bottom level flows through the lowered openings of rooms surrounding a courtyard, thus producing airflow. At night, the nice and cozy roof surfaces get cooled by convection and radiation. The next strategy that can be used in this climate is Jaali. So, Jaalis on the outer facade of the building help in cooling, shading, and ventilation. These Jalis, when used outside, also serve as a double wall.

And at the same time, Jaali's ventilation inside cuts the solar radiation and keeps the indoors cooler during the hot part of the year. So here, you can see how Jaalis can be used in different ways. Next is evaporative cooling. So, water is a good modifier of microclimate, and water features a moderating effect on the air temperature of the microclimate. It possesses a very high thermal storage capacity, much higher than building materials like brick, concrete, and stone.

4. Water can be used for two reasons. One is for evaporative cooling. And the second function is to increase the air humidity during the hot and dry period. During the hot and dry period. Increase the air humidity because the humidity can get reduced even up to 30%, making the air extremely dry, especially with a combination of extremely high temperature.

So, a water body can serve as an evaporative cooling effect, and normally, a combination of a courtyard plus a water body works best.

5. Then, thermal insulation is another strategy to prevent heat gain due to high thermal mass. You can have thermal insulation or have the building envelope composed of high thermal mass. So, having insulation is one strategy, and the second strategy is to have a high thermal mass. During the daytime, heat gain through solar radiation, occupants, and equipment inside is stored in the thermal mass.

Concrete slabs, precast ceiling panels, and heavyweight mass walls can add thermal mass to buildings. Traditionally, thermal mass was added with the use of mud walls. For night cooling, water or outside air is passed through the building at night to carry the heat stored in the thermal mass during the daytime. So, thermal mass can be used with night cooling or cooling the buildings passively. Diurnal swing, i.e.,the difference between daytime and nighttime outdoor temperature must be high for thermal mass to be an effective passive cooling and heating strategy. The next strategy that can be used in this climate is a wind tower. So, in a wind tower, the hot air enters the tower through the openings in the tower, gets cooled, and this becomes heavier and sinks down. The inlet and outlet of rooms induce cool air movement. In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living or habitable space.

After a whole day of air exchanges, the tower becomes warm in the evenings. During the night, cooler ambient air comes in contact with the bottom of the tower through the room. The tower wall absorbs heat during the daytime and releases it at night, warming the cool night air in the tower.

6. The next strategy we can use is passive downdraft evaporative cooling.

In this system, wind catchers guide outside air over water-filled pots, inducing evaporation and causing a big drop in temperature before the air enters the inside. Similar wind catchers come as the primary rudiments of the architectural form as well.

7. The next strategy is cool roofs. So, cool roofs are roofs that are covered with a reflective coating that has high emissivity, which is very effective in reflecting solar radiation away from the roof surface. This quality greatly helps in reducing the cooling load that needs to be met by the HVAC system.
8. The combination of an insulated roof with cool roofs has high energy-saving potential. Thermal emittance, like the re-radiation of absorbed heat, and solar reflectance, i.e., solar energy reflected back from cool roofs, is much higher than conventional roofs, which enables them to prevent solar radiation from being passed on to the interior of the building. Then, a roof pond is another strategy. The roof pond system requires a body of water to be located on the roof, which is protected and controlled by external movable insulation.

This body of water is exposed to direct solar gain, which absorbs and stores this heat. Roofs should also be properly insulated to minimize the heat transfer from the roof to the inside of the building. Providing adequate rainwater drainage is also essential in this climate. Next is natural ventilation. The orientation of the openings is determined by the ability to utilize the cooling effect of the breeze prevailing during the warm, humid season.

And to utilize the heat of the sun during the cold season, to cut off the ventilation during the cold part. So, one must be very prudent while using this strategy in composite walls because when the strategy is used for one climate type, it can become adverse during the other climate type. If this strategy of natural ventilation is used during the warm, humid period, it can become adverse during the hot, dry period and vice versa. The next strategy is the earth air tunnel. So, using the passive cooling effect of the ground, this device can lower the air temperature in the air duct by even up to 10.6 degrees centigrade.

Due to the rocky terrain of the site location, this technique cannot be used. Next is the green roof. So, stormwater runoff reduction happens when we use a green roof. Solar radiation intensity gets reduced inside the building. Thermal heat gain gets reduced.

Energy consumption is reduced. The impact on the urban heat island is reduced. Green roofs can even improve air quality and provide sound insulation. They can improve the longevity of roof materials and also provide additional area for the plantation of produce. So, green roofs can be another strategy for enhancing thermal performance.

9. Then, we look at green walls as a strategy. The next strategy we can use is vegetation. Trees and shrubs create different airflow patterns, providing shading and keeping the surroundings cooler during warm weather. Vegetation can be used for energy conservation in buildings by shading buildings and open spaces through landscaping, providing roof gardens or green roofs, and shading vertical and horizontal surfaces like green walls. It can buffer against cold and hot winds, change the direction of wind, etc.

So, vegetation is a crucial element in altering the microclimate of an area. It can prevent reflected light from carrying heat into the building from the ground or other surfaces. Additionally, the shade created by trees reduces the air temperature of the microclimate along the building through evapotranspiration. Providing deciduous trees on the southern side of a building is useful in a composite climate. So, today we have seen passive design strategies and advanced passive design strategies for designing in a composite climate.

We saw that the suggestive software gives Strategies for overall throughout the year, as well as during the crucial periods of the year. As an architect, use your discretion to follow which strategies must be used. Also, understand which strategies must be modified before using. Some case studies where these strategies have been applied in composite climbing.

The first one is the CII Saurabhji Godrej building in Hyderabad. So, the CII Saurabhji Godrej Green Business Centre in Hyderabad is a LEED-rated platinum building in India. It offers advisory services to the industry in the areas of green building, energy efficiency, water management, environmental management, renewable energy, green business incubation, and climate change activities. An office building built over four and a half acres of site for about 2000 square meters. It's a commercial office building and scored very high in LEED rating of 56 out of 60 in those days.

So, the campus is located in the High-Tech Financial District of Hyderabad, in close vicinity to Google, Oracle, and Deloitte. The site is surrounded by medium-rise commercial buildings. The location is also near landmarks like Shilparamam and the Hitech Exhibition Centre. The site gives a premier advantage to the employees by being near the residential zones of Kothaguda and Hitech City. It's an ideal zone for campus planning.

It is located on the flattest zone on the site with the least interference to site features during construction. It has easy access from the main road and is centrally located on the site. It has scope to create buffers surrounding the building for effective design according to the site climate, and this building is less prone to pollution. Let us look at the site plan. The site plan shows that there is a water body in the building on account of its topography, and closer to that is the designed root zone treatment plant.

This site is covered with a lot of vegetation. The concept of this design is based on the Panchamahabhutas, which is an ancient belief that states life exists because of the presence and balance of five classical elements. They are associated with the five senses. They act as the gross medium for the experience of sensations. Among these are the use of materials,

Being energy efficient, enhancing natural ventilation, provision for renewable energy, socio-cultural response of the site, having a good water management system, the concept of sustainability with reuse and recycle, and a lower carbon footprint. So the plan is a closed formation of concentric spaces with a courtyard in the middle. The plan is derived from the subtractive combination of several built spaces and green pockets. The arrangement of spaces is radial. Similarly, the structure is also radial.

The structural formation is derived from the circular arrangement of columns and the slanted combination of radial beams. The building has a semi-open circulation through public and semi-public spaces. The pattern of circulation is in two forms: radial and circular, merging to complete the free and open flow throughout the building. The spaces are vastly open to give maximum exterior green views. The elements that are used in this building are which aid as climate-responsive elements and also as simple and advanced passive strategies.

i. The first is a courtyard. A central courtyard and colonnaded corridors ensure that the hot air cools before entering the interiors. The courtyard also acts as an area for interaction. The plants collectively create a space of diffused light that just adds more to the liveliness.

ii. The second is the use of traditional elements. The walls are commonly experimented features in aesthetics with several arrangements and patterns. The walls allow a controlled flow of air and light into the interior space. Jali is used to prevent glare and heat gain while ensuring adequate daylighting. The jali walls increase the surface area and mass of the facade to cool much of the breeze in the passage.

iii. The third is the use of glazing for lighting. Now, the courtyard itself is a large light well that spreads light coming from the top. The 20,000-square-foot building is designed around a courtyard, a traditional gathering space for intellectual encounters, cultural functions, and social interactions, which acts as a light well providing light to the adjoining rooms. It helps in stack ventilation and forms a safe, inside yet outside environment. The natural light from the courtyard, combined with energy-efficient lighting systems, results in 88% energy savings, higher than that of an electricity-lit building of the same size.

Around 90% of the building spaces have daylight access and views to the outside. The north facades are fully glazed for efficient natural light. Low heat-transmitting glass has been used. Double glass has been used to further reduce heat gain. Double-glazed units with argon gas filling in between the glass panes also enhance the thermal properties.

The building design and layout itself ensure that 90% of the spaces have daylight access and views outside. The north facades are glazed for efficient diffused light. Low heat-transmitting glass has been used, and this double glass also doubles up to further reduce heat gain. Natural lighting has been used, and no lights are used until late in the evening. Light is captured from as many sides as possible, including the courtyards.

Help in having the rooms lit with maximum natural light.

iv. Next is water management. The conservation of water was of prime concern for this project. Here, they have used the root zone treatment plant, which helps in two ways. One is in the waste management of sewage as well as water conservation.

So, water generated in the building is treated with a root zone treatment plant, which is a process to treat wastewater through a biological mechanism. The treated water is used for irrigation requirements within the campus. The CII Godrej building campus has achieved 56 LEED points, and a key aspect of this is because of zero discharge of water. This is aided by the green roofs among other features. All the wastewater and runoff generated by the building is recycled by root zone treatment, which you would have seen in the site plan located in the lowermost area of the site.

This has specially selected plants which purify and filter the water that irrigates them. Water leaving the root zone treatment is directed to one of the three ponds, thereafter to be used for domestic purposes. The building achieves a 35% reduction of municipality-supplied potable water, in part through the use of low-flush toilets as well as waterless urinals. Rainwater harvesting is another important criterion. Some rainwater goes into the soil with the use of grid pavers used on roads for easy drainage of water.

The remaining rainwater follows existing flow patterns and is collected in the water pond. Wastewater is treated with the help of root zone treatment, and the treated water is also used for watering the landscape. It is also used for light and low-flush toilets with waterless urinals. The next aspect is ventilation through wind towers. Two air cooling towers are erected where air is cooled up to 8 degrees by sprinkling water.

This cool air is circulated inside the building, minimizing the load on air conditioning. The wind tower is connected to the AHUs, substantially reducing the load on the air conditioning system. Due to the unpredictable wind direction, openings on all four sides are provided with an additional effect due to the wind pressure. The next component is the terrace gardens. 55% of the roof is covered with a terrace garden, helping to reduce the interior temperatures.

20% of the building's energy requirements are catered to by solar photovoltaics. The solar PV has an installed capacity of 23.5 kW. Vertical landscaping has been used in certain areas and is an essential feature of this building. It has been used as a facade element, while some has been used as a partition element. Vertical landscaping is an influential element in enhancing the vibrancy of green buildings.

v. Apart from aesthetics, these act as additional mass to the wall and reduce the heat load in the building. Next, the uses of materials and resources. 80% of the building materials have a large proportion of post-consumer or post-industrial recycled content. The masonry construction has a considerable content of fly ash, which is an industrial waste. The walls are constructed using fly ash blocks and fly ash cement.

The ceramic tiles used for flooring have cullets, broken tiles, papers, etc. Instead of conventional ply or wood, the project used a composite agro board manufactured from bagasse, which is a sugar cane waste. Local and regional materials have also been used, and 95% of the materials used in the project were harvested, extracted, or manufactured within a radius of 500 miles. 65% of the walls are constructed with fly ash bricks, which feature a cost reduction of 20% less than traditional clay bricks that are normally used. These are lighter than clay bricks, have high strength, practically no breakage during transport, and have high recycled content.

Bagasse board is a by-product of the sugarcane industry. It is low-cost and durable. It has wide usage for making partitions, furniture, etc. The waste management plan ensures that 95% of construction waste was recycled. Further, some industrial wastes like broken glass, broken tiles, broken stone, recycled paper, and recycled aluminum have also been used.

vi. The next important feature is the indoor air quality. Indoor air quality is continuously monitored, and a minimum amount of fresh air is pumped into the conditioned spaces at all times. Fresh air is also drawn into the building through the wind towers. The use of low volatile organic compound paints, coatings, adhesives, sealants, and carpets also helps to improve indoor air quality.

Hydrofluorocarbon indicates that the refrigerant is composed of hydrogen, fluorine, and carbon.

HFC refrigerant gases are considered to be more environmentally friendly because they are the third generation of fluorinated refrigerant gases. They are developed to be a more environmentally friendly and definitive alternative to CFC and HCFC. Other notable green features are the fenestration maximized on the northern side, the use of rainwater harvesting, waterless urinals in men's restrooms, water-efficient fixtures which are ultra-low and low-flow flush fixtures, HFC-based refrigerant in chillers, and energy-efficient lighting systems through compact fluorescent light bulbs. They have large vegetative open spaces, swales for stormwater collection, maximum daylighting, operable windows, and lighting controls for better daylighting and views, electric vehicles for staff use, and shaded car parks. So, the CII Godrej has tried to use many technologies.

Simple passive systems as well as advanced passive systems suitable for their climate, along with other features, have earned them the LEED platinum-rated certification. We will quickly see another case study, which is PIDA, Punjab Energy Development Agency, an office complex in Chandigarh. So, PIDA Chandigarh is a state nodal agency responsible for the development of new and renewable energy and non-conventional energy in the state of Punjab. This is a solar passive complex in Chandigarh designed by architect Arvind Krishnan. It is a five-star rated building under the Bureau of Energy Efficiency star rating of government building schemes.

This project aimed at demonstrating an architectural design developed in response to elements of nature, which are the sun, wind, light, and utilization of solar passive systems. The context of the site analysis shows that the building design needs to respond to a composite climate context of the site, and the final design solution needed to satisfy the diverse and often conflicting conditions of the hot, dry, hot, humid, temperate, and cold periods of Chandigarh. The climatic conditions were 2 months of hot dry, 2 months of hot humid, 2 months of cold period, occasionally hazy skies with hot winds in summer, low humidity in summer, high in monsoon, cold winds in winter, and strong winds in the monsoon. The strategies required were cooling in the hot dry period, natural ventilation in the hot humid period, heating in the cold period, and cooling remained as the predominant requirement since the total overheated period extended from mid-April to mid-August.

The orientation of the building became an important simple passive technique to be considered. The building has a three-dimensional form responding to solar geometry, minimizing solar heat gain in the hot dry period and maximizing solar heat gain in the cold period. The site is minimal in size, and the building is the result of the shape of the site. It was, therefore, not possible to orient the building in a specific direction. The entire facade of the complex has used different strategies to reduce heat gain during the summer.

The design of the building envelope reduces the effect of the external atmospheric conditions on the interior spaces. The central atrium of the complex is covered by a lightweight hyperbolic shell roofing of 10 cm of high-density extruded polystyrene, which is sandwiched between high-grade fiber-reinforced plastic sheets and reinforced with steel. Daylighting has been used. With the help of the atrium, which is specifically angled to allow the sun in during winters and block it in the summers, only admitting glare and heat-free daylight. The hyperbolic shell roof is coupled with solar panels sandwiched between two sheets of toughened glass, which not only generate electricity but also let diffuse daylight into the central atrium.

The concrete domes structured on the southwest facade are one of the well-recognized innovations of this project. These domes have horizontal and vertical intersecting fins with glass fixed in the voids. These voids allow natural light with reduced glare. The shading action of the fins allows indirect sunlight to enter the building in summers and direct sunlight in winters. Cutouts in the slabs make it possible for this natural light to reach multiple floors.

Next is ventilation. The water element consists of water bodies and fountains. Fountains are operational during hot and dry months, i.e. April to June. They help decrease the interior temperature through direct evaporative cooling.

The wind tower has a mechanical component, the ambiator, and uses the method of indirect evaporative cooling, in which water cools the air without coming into contact with it. Solar chimneys have been used and placed atop the light walls. These are used to expel hot air from within the building. In turn, fresh air rushes in from the openings in the envelope, passes over the floor, heats up, and escapes through the lower top. Insulation has been used.

The walls are made up of two layers of bricks with a 5 cm air gap in between. These cavity walls In the southern and western facade have insulation consisting of 60 cm by 60 cm panels of 6 cm thick rock wool wrapped in polyurethane sheets. These have been placed between the layers of bricks in addition to the air gap. The combination of a brick wall with an air gap reduces heat transfer by 50%.

As compared to a conventional brick wall. If insulation is added along with the air gap, the heat transfer decreases by 85%. The atrium roof is a central hyperbolic shell roof with 10 cm of high-density extruded polystyrene sandwiched between high-grade fiber-reinforced plastic sheets. The concrete roof The maximum heat gain is through the roof.

A rock wool and polystyrene insulation with an air gap of 5 cm from the concrete slab has been placed. The top layer is made of mud fusca and brick tiles for further heatproofing. So if you see, the overall building looks like this. It has a series of advanced passive strategies like the use of a solar chimney, the use of light wells, the use of solar PV panels, and having a wind tower. So I am not going into the description of what is a wind tower or a solar chimney because we have done it for so many of our previous case studies.

The PIDA building demonstrates a great example of a passively designed building in a composite climate. Numerous passive strategies, such as the southern dome structure, water bodies, wall insulation, double walls, or rather cavity walls, have been used and complemented by other advanced strategies like wind towers, solar panels, etc. The design of the building is equally as important as the passive strategies applied for them to work well. The open plan of this building makes it possible for the benefits of the passive and active strategies to be useful throughout the building. The integrated PV solar panels placed on top of the atrium roof produce electricity.

25 kilowatts of power to meet the basic electric requirements of the office. So, this PIDA office has an EPI (Energy Performance Index) of 14 kilowatt-hours per square meter per year, which is one of the lowest in the country in the category of non-air-conditioned buildings. For perspective, the EPI of commercial buildings is above 180 kilowatt-hours

per square meter per year, and the benchmark set by BEE for buildings compliant with ECBC 2007 is 140 kilowatt-hours per square meter per year. This itself shows it's an energy-efficient building. So, today we saw case studies of buildings that are designed for climate responsiveness in a composite climate.