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

Week: 05

Lecture 01

Openings- Size, Position, Shading device- Part 1

Hello everybody. Last class we saw orientation and form as a simple passive strategy. In today's class we will move to another strategy which is opening. We will look at the correct way of sizing, positioning and opening and also a shading device. So this we will carry out in two parts. Today we will look at the first part.

We will today look at shading and its types. Designing of shading devices, positioning of windows, energy consumption with shading devices, and energy consumption with window position. So research conducted in Hong Kong revealed that implementing energy-efficient envelope design could potentially reduce cooling demands by up to 35%. Similarly, a study in Malaysia highlighted that cooling accounts for a significant portion, approximately 46 percent, of the total energy used in high-rise office buildings.

So, external shading devices, whether constructed from building materials or living plants, have been shown to decrease indoor cooling loads by 30 percent. Further findings suggest that shading devices are more effective at reducing cooling energy consumption compared to the utilization of high-performance glazing. Even plant-based external shading solutions have demonstrated significant benefits. For instance, a study conducted in Penang using a vertical green system reported a remarkable reduction in facade surface temperature of up to 6.4 degrees centigrade.

These studies underscore the potential of external shading strategies, both conventional and innovative. It significantly helps in mitigating cooling energy demands and enhancing the building's energy performance in diverse climatic factors. However, here we will be focusing on permanent structures used for shading in buildings. So, let us look at window sizes. Now windows are complex, multifunctional, carbon-intensive, expensive, difficult to get right, and too often they are designed primarily for aesthetics.

When necessary, windows allow natural light and the direction of the wind to enter the building. However, significant heat gain may result from solar radiation that enters the room through the windows. Size and orientation of windows are two ways to minimize heat gain. Windows can also affect the possibility of harnessing sunshine by lowering lighting loads without sacrificing the thermal and visual comfort of building occupants. A precise calibration between the orientation and sizing of openings as well as the visual and heat transmission properties of glass is necessary to achieve a balance between heat gain and daylight penetration.

In terms of both quantity and duration, solar radiation intensity is lowest on north-facing walls or openings and is highest on south-facing facades between the north and the south wall. Between east and west, the east solar radiation is lower and the west solar radiation is extremely high. Walls or openings facing these, if they get a lot of sun, can become extremely hot in warm-humid and hot-dry conditions, or they can become very comfortable in cold areas. Let us briefly look at heat transfer through windows. So heat transfer through windows happens in this manner.

Through the frames of the building there is conduction of heat. So heat gets transferred due to conduction. then the incident solar radiation that falls on the glass that partially gets transmitted, partially gets reflected, and partially gets absorbed by the glass, which in turn could get conducted to the room air near the room. This percentage of transmitted rays, reflected rays, or absorbed rays depends upon the type of glass. So, the nature or type of glass is important for this.

This absorbed radiation is re-emitted partly inside and partly outside. Also, there is convection heat transfer happening, and there is conduction by the glass itself. So, heat gets conducted by the glass. Besides this, if the gaps are not well sealed, then there can be infiltration heat gain. Windows are carbon-intensive, and they are also a source of leakage.

We need to understand window-to-wall ratio as that is the measure of percentage of openings. So, when we talk of the amount of openings that is normally measured in window-to-wall ratio,. So, the window-to-wall ratio is the net glazing area divided by the gross wall area. So, here we can see it is just an indication to show what a 10 percent WWR means. So, a WWR of 10 percent looks like this and a WWR of 40 percent looks like this, a WWR of 80 percent looks like this and a WWR of 100 percent means almost the entire wall is made up of glass that is what it on more or less comes up to.

A study was conducted using ecotech on the impact of window size and position on the heating and cooling load in an air conditioned building in Gaza Strip and this is what the studies showed. What they had done was- they had taken different percentages of window-to-wall ratio and positioned it in three different locations. One was a low position, one was a middle position, and one was a high position. In this way, they had a matrix of 10 percent opening, 20 percent, 30, 40, 50, 60, 70, 80, 90, and as I said, 100 percent means it is more or less the entire wall. Again, for all these varying percentages, the location or position of windows were in three zones.

One was low, one was middle, and one was high. So, high, middle, low. So, low, middle, and high were the window positions. And then the window dimensions were also recorded. Now, you can see the effect of window size on the cooling load.

So, you can see that as the window size increased, the cooling load increased up to 90%. But there is an exponential rise when the window size is 100%. If we look at the heating load, again the heating load comes down exponentially only as a graph. The heating load comes down for up to 90%. There is a drastic reduction in heating load between 10% and 20%, and there is a sudden increase in heating load when the window opening increases from 90% to 100%.

The effect of window size on total loads follow the similar pattern to that of the cooling load where the total load increases gradually in a linear manner up to 90 percent and then there is a drastic increase in the total load when the window size becomes 100 percent. Now, the previous study was done using Ecotech in Gaza Strip and was not field based. There is another study which is done which is a field based research where the window sizes were gradually increased from 5 percent to 100 percent. So, about 14 opening conditions in terms of size ranging from 5 percent to 100 percent as shown in this graph and this study was conducted with 8 orientations. So, the rooms had So, this study was conducted in rooms with 8 different orientation.

This is the cardinal orientation and another 4 orientation was semi-cardinal. For the northeast wall, say this is the northeast room, southeast room, southwest, northwest. Here in this slide we are discussing the indoor temperature in this northeast room alone ok. So it is found that the indoor average temperature is almost equal to the outdoor average temperature when opening sizes are very large. But for opening sizes in the range of say 45% to 30%, the indoor average temperature is higher than the outdoor average temperature.

When the opening sizes are large, the prevailing wind direction helps dissipate indoor heat. As the size of the opening decreases, the thermal mass of the room takes over because the windows become small. The wall slowly releases absorbed heat into the room which the prevailing wind is unable to dissipate and the indoors become hotter when the opening sizes are small. In general, the number of comfort hours increases with decreasing opening sizes. This study showed that the northeast room is most comfortable when opening sizes are large. The north-west and the north-east north-west.

That is, the north-east room and the north-east north-west room are most uncomfortable for larger openings. That is, the north-west and north-east north-west rooms is most uncomfortable for large openings. These two rooms. The southwest rooms are most comfortable for small opening sizes. This room is most comfortable for smaller openings.

or mid-size openings. The northwest room is most comfortable of all the rooms when the opening sizes are small. So, the thermal capacity of the wall depends upon the quantity of wall surface as against the openings. Along with the solar radiation and wind, the thermal capacity of the wall contributes to the indoor temperature When the wall areas are large. When the opening sizes are 15% to 0%. When opening sizes are small, wall areas are large.

So, this study was completely done using field-based data. Indoor air temperatures in all the 8 rooms were measured using instruments for continuous periods during the summer time in Chennai. And then here I am specifically taking only the northeast room to demonstrate how size of the window matters with respect to the indoor thermal performance. We will also see one more example. So, here we are taking the southeast room as I had told you.

Here as I had told you, this is how the rooms were built. So, this is northeast, southeast, northwest and southwest. This is the north point. So, we will see the effect of window size in the southeast room also just as an example. So, the indoor temperature is high for small openings and low for large openings in the northeast and southeast rooms.

The difference in temperature at certain times due to variation of opening size can be as high as 40. 5 to 6 degree centigrade. See you can see in this graph you can see temperature in the southeast rooms for the varying opening sizes. So, you can see that this one which is say 35 degrees. So, in this graph, you can see for the southeast room what happens for all the varying opening sizes.

35 degrees seems to be peaking, and then you also have opening sizes, which is about 60 degrees, which is low. And then the 100 degree gets lower and then slowly increases, and so on. So, even just because of the change of opening sizes, we can get a temperature difference of about 5 degrees to 6 degrees centigrade. So the indoor average temperature is almost equal to the average temperature when opening sizes are large. But for opening sizes in the range of 45% to 30%, the indoor average temperature is higher than the outdoor average temperature.

When the opening sizes are large, the prevailing wind direction helps dissipate indoor heat.

As the size of the opening decreases, the thermal mass of the room again takes over. The wall slowly releases absorbed heat into the room, which the prevailing wind is unable to dissipate, and the indoors become warmer when the opening sizes are small. The indoors are uncomfortable for all opening sizes from 10 o'clock in the evening till 5 o'clock in the southeast rooms.

That is almost 34% of the day. As the opening size reduces from 50% to 5%, the comfort hour decreases and the indoors become uncomfortable. These rooms are suitable for habitation in the late evenings, either at night or in the morning. We will look at another orientation, which is the southwest room. So, this time we are looking at the southwest room. How does the southwest room perform? with varying opening sizes.

So, the indoor temperature rises gradually from 6 o'clock and reaches its peak at about 1.30 to 2.30 pm in the afternoon, depending upon the window size. The rate of fall of indoor temperature in the evening is low as the western wall releases the absorbed heat. The indoor temperature falls only by 2 degrees centigrade from 6.30 in the evening to midnight (1.30), that is, in 7 hours time. Hence, as the opening sizes decrease, that is, the wall area increases by 50 percent, and the indoors are relatively warmer. A temperature difference of about 6 degrees can be achieved during certain periods of the day by altering the size of the openings. So just by tampering with the opening size, we can have a 6-degree variation in indoor temperature during certain times of the day. So, the indoor average temperature follows the outdoor average for large openings.

So, when opening sizes are 100 percent to 50 percent, the average temperature follows the average temperature of the room and follows the trend of the outdoor average temperature. But as the opening size decreases from 45% to 25%, the indoor averages are higher than the outdoor average. The indoors are uncomfortable for 30% of the day for large openings. As the opening size decreases, the percentage of comfort hours also decreases and occupies 55% to 45% of the day. This completely field study-based research was actually done by me.

So, I have done this through a funded project by the AICTE, and I am thankful to AICTE for having funded me to carry out this project. Then let us look at the window orientation or position for various climate types in India, and we will look at the hot and dry, warm and humid, composite, moderate, and cold. So, in hot and dry weather, the best window position is the north and south orientation. For warm and humid, the best window orientation is along the north and south.

Composite climates south is a better orientation. For moderate and temperate climates, north is a better orientation. For cold climates, south and east is a better orientation for the windows. Let us look at the window criteria for hot and dry climates. Climate regulation is a critical factor in architectural design, especially in hot and dry environments. High temperatures and bright sunshine make it difficult to keep pleasant indoor spaces.

Architects can use small window openings as a design technique to effectively solve these problems. While windows and openings are essential for natural ventilation and illumination, summertime heat gain should be kept to a minimum. Ideally, there should be no openings during the day, especially on the west side. If there are, for any reason, they should be small, insulated from direct radiation, and high up on the walls to avoid ground radiation. The window ought to be big enough to allow at least sufficient night time ventilation to disperse the heat that the roof and walls emit.

Larger windows should therefore be opened at night and covered with insulated shutters during the day because these systems depend on the residents attendance and readiness. They are not always dependable. Let us look at the window criteria for hot-dry climate, size, and orientation of the window. The main windows should face both north and south, but the latter should be partially shaded either with deciduous trees or roof overhangs, chajjas, or any shading devices. This will prevent heat gains into the house in the early morning and late afternoon.

Windows on the west and east sides should either have their sizes reduced extremely or should be covered by special shading mechanisms. A glass region that faces south somewhat receives solar radiation in the winter, but it should not be exposed to direct sunlight in the summer. Otherwise, the area closer to that would feel like a bakery. It would be extremely hot like a furnace.

Let us look at how windows should be placed. Window should be placed in suitable positions in relation to the prevailing breeze, which should be cool to allow a natural air flow to the building to achieve air movement across the body for evaporative cooling. and air changes for driving out excess heat. An internal draft like cross ventilation can be channeled by louvers that are set in an upward position towards the ceiling or in a horizontal position towards the human body. Outlet openings should be located at a high level where hot air accumulates. In buildings in coastal areas, openings for cross ventilation should be equipped with movable shutters.

Because of the hot land wind that occurs at night, openings facing the inland direction should be closable (operable). For comfort, ventilation openings should be at the level of the occupants. High-opening vents collect hot air near the ceiling and are most useful for convective cooling. Let us see what should be done in the warm-humid climate. Now windows have a very important role in controlling the interior temperature in a warm and humid climate.

To provide for adequate cross ventilation, there should be fully movable inlets on both sides of the room that are of similar size. The best windows have movable louvers that let you control the amount of air flow. Louvers and grills are additional options for door shutters. Fixed glass pane windows offer no benefits, and they should be avoided. Positioning windows in accordance with the direction of the predominant winds will allow natural ventilation throughout the interior space.

Concentrating this airflow at body level maximizes its effectiveness. The ideal position for bedroom windows is to pivot or raise them to the level of the bed in order to direct airflow towards the sleeping surface. In warm and humid climate, fixed glass pane windows offer no benefits and should be avoided. Positioning openings in accordance with the direction of the predominant wind will allow natural ventilation throughout the interior space. Concentrating this airflow at body level maximizes its effectiveness.

The ideal position for bedroom windows is to pivot or raise them to the level of the bed in order to direct airflow towards the sleeping surface. Window-to-wall ratios of 10 to 30% in bedrooms and 20 to 30% in living rooms allow a good balance between adequate daylight and reduced heat gains. So, when we look at the design and placement of windows in a moderate and cold climate. Windows should be of medium size with openings on opposite walls for proper cross ventilation during the humid period.

On the west and north sides, windows should be small. As a rule of thumb, the total window area should not exceed 25 percent of the floor area. In upland areas, as many windows as possible should be located on the south side of the building to utilize the heating effect of solar radiation. However, the glazed area should not exceed 50% of the south elevation because of extensive heat loss at night. So, with this, we will stop today's class of opening size and position, which is part 1. In the next class, we will continue with the other aspects of how openings and shading devices should be designed and placed. Thank you.