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 02

Openings- Size, Position, Shading device- Part 2

So, hello students. The last class we saw one another simple passive strategy, and that is opening size and position. How we have also seen studies that show the impact of opening size and position on the indoor thermal performance of buildings. So, definitely, opening size and position has an impact that is a given. Today we will continue with the same topic. So, we will look at opening, size, position, and shading device.

This will be the second part. So, if we look at shading today, we will look primarily at shading. Structural controls like external shading devices are essential environmental controls that either obviate or greatly reduce the need for mechanical heating and cooling to maintain thermal comfort inside buildings by controlling heat gain through openings. Along with the glazing type and size of the fenestration or window, shading devices are equally important in limiting heat gain from outside through radiation.

External and internal shading devices can thus be used as an essential solution for achieving energy efficiency. The orientation of building openings significantly influences the design of external shading devices, with solar radiation incident being a key consideration. Seasonal variations in the sun path are directly linked to orientation impacting the angle of solar radiation. During winter, in the northern hemisphere, the sun path is low and slightly south of east and west. In contrast, summer sees a higher sun path north of east and west.

For south facing openings, shading must balance allowing low-angle sun penetration for winter heat gain while blocking it in summer. North facing openings require shading mainly to prevent high-angle summer sun penetration. East and west-facing openings experience relatively uniform solar radiation throughout the year compared to north and south-facing ones. The intensity of solar radiation is very harsh on the west-oriented openings. Solar control and shading can be provided by a wide range of building components, including landscape features such as mature trees or even hedges and shrubs.

So it's not necessary that one has to necessarily have a sun shade or a porch or something like that as a shading device. But having trees can also shade the opening considerably. If you see in this picture, you have a deciduous tree. So this is a deciduous tree, and what it does is shed its leaves in the winter. What happens when it sheds its leaves? It allows the winter sun to enter.

But in summer, it blocks the summer sun. So, we can use such landscape features also. Exterior elements such as overhangs or vertical fins can be used, as shown in the first picture. The horizontal reflecting surfaces there can be used; these are called light shelves, and these can also be used. Low-shading-coefficient glass and interior glare control devices such as venetian blinds or adjustable lowers can also be used.

Let us now look at the types of shading. So external shading devices must align with wall orientation and building location to determine when shading is required daily and annually, as well as the angle of solar radiation. Shading masks, graphical representations of shading—these aid in designing effective shading strategies. Some of the types of opening shadings are overhangs. Overhangs are best for south-facing windows where the sun is very high.

The high overhead sun during hot summer months, whichever places they have overhangs, is necessary, and a relatively short overhang can provide effective shading. So this is an overhang, which is a shading sun shading device, and you can see how it shades the sun and casts the shadow. The longer the shading device, the more it is going to cast the shadow. So, in a hot, humid climate, say in some of the tropical countries, it is best to have at least an overhang. Then second is awnings.

Awnings like overhangs block the sun effectively. Awnings often extend further than overhangs work, and normally they are considered to be best on east and west facing wall. So these are awnings. However, on all the walls, what works best, at least in the tropical country, is the sun. is overhangs at least.

Then you can have exterior roller screens or shades and shutters. So, roller screens, shades, or shutters are more common in Europe. They block sunlight before it strikes the window. So, having external roller screen curtains or screens completely blocks the sun rather than providing shade on the glass. So they block sunlight before even the sunlight hits the window, and some products provide high wind protection too.

In the US exterior roller shutters are used primarily in coastal locations that are prone to hurricanes. More shade screens allow some visibility even when fully deployed. Then the fourth type is the vegetation. Having trees, I mean, having creepers or shrubs close to the window or deciduous trees. So these block the sunlight in the summer.

In the winter, when it sheds its leaves, it allows sunlight to penetrate. Greenery also provides important psychological and health benefits for residents. Then we can have some interior treatments for blocking the sun. First are the blinds and curtains. The simplest and least expensive interior shading systems are blinds and curtains.

Insulated window blinds, either cellular or quilted, are more effective in shading than simple pull-down shades. So we can have venetian blinds inside. which will allow us to have control over how much shading is required, or we could have curtains and screens. So, sometimes these can curtains and screens can also be used. Also, instead of the horizontal shade, we can also have vertical shading devices, vertical shades.

which will shade the window effectively. So, these are very broad categorizations of shading devices. We will continue. So, to minimize solar gain, so, to minimize solar gain prioritize a north-south orientation for buildings And maybe a south-facing window which is easily shaded with fixed horizontal overhangs or vertical fins depending upon the climate effectively blocks summer sun and allows winter sun. Limiting east and west glass reduces the need for shading, which is important because allowing too many openings on east and west is going to bring in a lot of solar radiation inside the building or the room, and landscaping can provide additional shade for these exposures.

An extended roof can provide shade to the entire north and south wall from the moon sun. Shading generally is not required on the north side as much as it is required on the other sides. Only cutting the low evening summer sun can be achieved by vertical shades or internal blinds. On lower buildings, well-placed deciduous trees on the east and west will reduce summer overheating while permitting desirable winter solar gains in the cold part of the country. Semi-outdoor spaces such as balconies can provide shade to the glazing or windows on the lower part of the buildings.

And these can be even up to two and a half meters in depth. So, to enhance natural light passive design strategies such as light shelves, they are very useful for deeper and uniform distribution of light, which are most effective on the south side of the buildings, and these are mostly recommended in milder climates and definitely not for tropical or desert climates. So, if we look at the varying types of shading devices, we can see that there are shading devices that are combinations of a horizontal sunshade as well as screens. So, one is a combination of sunshade and screen. 2 is having multiple smaller sunshades so that the entire window from top to bottom gets shaded.

So, both 1 and 2 can enable shading of almost the entire window. If the depth of the shading device is less, then you can have multiple horizontal shades. Again, this will ensure that the complete window or glazing gets shaded. At the same time, there is no compromise in numbers 2 and 3 in terms of day lighting and ventilation.

This one is 4. So the fourth slide shows one small sunshade and one longer sunshade. So, this controls to some extent the amount of solar radiation falling on the glass as well as the day lighting. We also have a combination of a horizontal shading device as well as a vertical shading device. This can also be effectively designed to shade the entire glazing. A combination of horizontal as well as vertical shading devices gives rise to an egg crate.

egg crate shading device. So, the egg crate shading device can be like number 6 or illustration 7. There can be various designs. Again, number 8 shows that there can be varying sizes of the egg crates. Besides this, you can have vertical fins and combinations of horizontal and vertical fins, which is demonstrated in figures 9 and 10, which have two horizontal shading devices and multiple vertical shading devices. Illustration 11 is a combination of horizontal and vertical shading devices.

A variant of awning is 12 and 13 is a variant of vertical shading device along with horizontal shading device. So, is 14. You can see that 15 and 16 are largely external blinds or venetian blinds. So, these are the various types of shading devices.

So, let us look at this case study. So, careful consideration of building shading is essential for energy conservation. Studies indicate significant energy savings, with up to 11.3% achieved through external shading in hot and humid climates. However, many shading devices prioritize aesthetics over energy efficiency, which should not be the case because the primary purpose of a shading device is its energy efficiency and not how it looks or how beautiful it is. Designers often overlook the importance of shading, delaying the analysis until later design phases.

Early stage attention to shading is crucial, particularly for facades with high window-to-wall ratios. By integrating energy-saving shading strategies early in the design process, buildings can optimize natural light and thermal comfort while reducing reliance on mechanical systems. All this contributes to sustainability and cost savings over the building's life cycle. Therefore, prioritizing shading considerations from the outset enhances energy performance and supports environmentally conscious design practices. This example has been taken from a research paper, and the paper investigates the efficacy of external shading devices in enhancing energy efficiency in Malaysia's hot and humid climate.

Through BIM simulation, it assesses how different configurations of these devices impact the energy consumption of a school building. This research aims to discern the extent to which various shading setups can reduce cooling energy usage. Understanding the effects of diverse shading configurations is vital for devising strategies to mitigate energy consumption in buildings, particularly in regions with challenging climate conditions like Malaysia. By elucidating the role of external shading devices in lessening cooling energy demands, this study provides valuable insights for architects, engineers, and policymakers striving to promote sustainable building practices and addresses the environmental impact of energy usage in tropical countries. This study was conducted on an office building, and the floor plan of this building is as shown in this figure.

So, the ground floor plan, the first floor plan, and the second floor plan are shown here. So, seven shading device models were examined, and they represent the common forms used in buildings in this part of the world. The shading behaviors of these modes illustrate how each configuration affects the building's cooling loads, offering insights into the efficiency. By analyzing the influence of different shading device setups, the study aims to discern which configurations effectively reduce cooling demands. This exploration of shading device variants provides valuable data for understanding their impact on building energy consumption, guiding the selection and implementation of efficient shading strategies in architectural design.

The seven shading options along with one more, which is the egg crate, are shown here. The first option is no shading. The second option has one horizontal shading device. The third option is two horizontal shading devices.

The fourth option is double inclined. So two numbers of inclined horizontal shading devices. The fifth one is horizontal louvers. Sixth option is vertical fins. The seventh option is slanted vertical fins.

And the eighth option is an egg crate. So, if we consider the first option no shading as a condition where no shading device is used, then seven different options of shading devices, along with one no shading, are considered in this study. So, in this table, after analysis It is seen that when we look at the comparative analysis of cooling energy consumption, say this was supposed to be a school building. The study was done on a school building in March and September; it highlights the efficacy of different shading devices. In March, the egg crate shading device stands out as the most effective, reducing cooling energy consumption from about 45000 kilowatt hour to 25000 odd kilowatt hour, resulting in savings of about 20000 kilowatt hour. The horizontal inclined double panel ranks second in efficiency, while the horizontal single panel demonstrates the least effectiveness, saving only about 1455 kWh.

In September, the egg crate shading device remains the most efficient, achieving a 49.63% reduction in cooling energy consumption compared to the March baseline without shading. Conversely, the horizontal single-panel shading device exhibits the lowest effectiveness, reducing cooling energy consumption only by 8 percent compared to the March baseline. So, we can also see in this table the electricity used for cooling in March versus the electricity used for cooling in September. In March, we can see that the egg crate has the least when the egg crate is used, the electricity used for cooling is least and the electricity as compared to the base case which has no what shall I say no shading device.

The least difference between the base case and a shading device is when there is a single panel, and a little less than half of it comes for the egg crate. So, the egg crate stands out to be one of the most efficient. When it comes to September, yes, the egg crate is very efficient in cutting the electrical consumption, and next to it comes the horizontally inclined double panel. So, definitely shading devices have an impact on energy consumption, and definitely it leads to a more sustainable output. So, in this figure, this illustrates a consistent trend in energy consumption between March and September, and we can see that egg crate, this is March; egg crate has the least energy consumption for March, and also egg crate has the least energy consumption for September.

So, this stands out as number 1. We can see that the horizontal panel and single panel are the least effective. So, this can rank as 7th. This is least effective in both March and September and after egg. A crate horizontally inclined double panel is most effective in reducing energy use for March as well as September. The horizontal inclined double panel and horizontal double panel perform more or less similarly with very little difference.

Let us now look at the position of windows. So, in the previous class we had seen about the size of windows; in this class we have seen the shading device, and now we will look at window position. So, the location of window openings within a building's external wall significantly impacts the level of natural lighting and ventilation. Previous research has investigated how factors such as direction, size, and proportion of these apertures influence indoor lighting. Studies indicate that window positions with centers aligned along the vertical wall axis coupled with a window-to-wall ratio of 10 to 20 percent yield consistent natural lighting levels. Conversely, openings aligned along the horizontal wall axis tend to offer more uniform lighting and greater efficiency, particularly as the aperture ratio increases.

Additionally, research suggests that window-to-wall ratios around 20% notably enhance the effectiveness of window openings in facilitating natural lighting and ventilation. These findings underscore the importance of strategic window placement and sizing in optimizing natural light penetration and airflow within indoor spaces, thereby promoting occupant comfort and energy efficiency in buildings. The example selected here is from a research paper for better understanding. The case of a window-to-wall ratio of 20 percent is selected here. As we have already seen, WWR stands for the window-to-wall ratio, which is a measurement used in building design to express the proportion of a wall that is occupied by windows compared to the total surface area of the wall.

It is typically expressed as a percentage and is an important factor in determining the amount of natural light and ventilation that can enter a room. A higher WWR indicates more windows relative to the wall area, which can lead to increased day lighting and views to the outside. But this may also impact energy efficiency and thermal comfort, as we have already seen in the previous class. So, builders and architects often consider WWR when designing buildings to achieve desired levels of natural lighting, visual comfort, and energy performance. So, in this research case, for the position of the windows, five positions were chosen.

The position here is that the window is placed above in the centre. The first condition is when windows are placed on the centre of the wall. The second condition is when windows are off centered towards the bottom of the wall. The third condition is when windows are placed or positioned towards the top of the wall or towards the ceiling. The fourth position is when windows are off-centered to the right, and the fifth one is when windows are off-centered to the left.

In this manner, there have been 5 windows that are positioned, thus the size of the windows is 5 in number. So, 5 windows, 5 positions are selected. And then the annual energy consumption of the different window positions on the north wall—this is the north wall—and the south wall is analyzed. The lowest annual energy consumption occurs on the north facade.

as compared to the south facade. Among the various window configurations, the square window positioned on the upper part of the wall records the minimum energy consumption, and that totals to about 3350 kilowatt hours per year. Following this square, here we will see this. So, this is the square. this is the horizontal, this is the vertical, this is the horizontal striped thin one and this is the vertical. So, among the various window configurations, the square window positioned in the upper part of the wall records the minimum energy consumption.

So, of all the others, this records the minimum energy consumption. Following this, the square opening on the left of the wall that exhibits a slightly higher energy consumption is succeeded by the 2 is to 1 ratio window, and finally, the 3 is to 1 ratio window, which is here. Notably, placing the window at the bottom of the wall results in increased energy consumption compared to the 1 is to 1 square window configuration, but it is less than the 2 is to 1 window. Conversely, the highest energy consumption is observed when a rectangular window 3 is to 1 window, totaling 3750 kilowatt hours annually, marking an increase in approximately 400 kilowatt hours from the lowest value in this orientation. When it comes to the southern facade, there is some difference. The energy consumption notably exceeds that of the northern wall and the eastern facade.

Among the various window configurations, the rectangular window with a 3:1 ratio. So, this is the rectangular with a 3:1 ratio. Position at the upper part of the wall records the lowest energy consumption for this facade. This is followed by the window in the center of the wall and then the upper part of the wall with ratios 2 is to 1 and 1 is to 1, respectively. Interestingly, the 1 is to 2 and 1 is to 3 windows result in nearly similar energy consumption for both the center and left positions in the wall.

Conversely, the highest energy consumption for this facade is attributed to the bottom windows with ratios of 1 is to 1, 2 is to 1, and 3 is to 1, with energy consumption increasing in ascending order relative to the window ratios. If we look at the east and west walls, it is evident that the energy consumption on the eastern facade decreases notably when utilizing the upper 1 is to 1 square window configuration. However, the square opening positioned in the center of the wall results in relatively higher energy consumption, while the 2 is to 1 and 3 is to 1 openings cause even greater consumption compared to the former. Notably, the lower openings contribute significantly to increased energy consumption. Moreover, it is observed that as the width of the aperture increases relative to its height, energy consumption rises accordingly.

Specifically, the ratio of 3 is to 1 exhibits the highest energy consumption, totaling 3800 kilowatt hours, surpassing that of the 2 is to 1 and 1 is to 1 ratios. The western facade exhibits the highest annual energy consumption compared to other facades as depicted in these diagrams. Interestingly, the upper and center rectangular 3 is to 1 window configuration yields the lowest consumption for the facade. Conversely, the bottom rectangular 3 is to 1 window configuration results in the highest consumption. The vertical rectangular window configuration yields nearly identical energy consumption across various facade directions and positions except for the right position, which triggers an increase in approximately 100 kilowatt hours.

So, this is a very interesting study where these 5 positions of windows with 5 sizes of windows are taken, and then it is found which has the most effect and which has the least effect on energy consumption. So, in general, we conclude that the northern facades exhibit a 15 percent to 25 percent lower annual energy consumption compared to other directions.

When considering a 20 percent window-to-wall ratio, the maximum annual energy consumption difference for the administrative room varies by up to 400 kilowatt hours across different window positions for each facade direction. This accounts for approximately 10 to 11 percent of the total energy consumed for a given facade direction with varying window positions. To summarize, for the tropical climates, the most appropriate building orientation to minimize solar heat gain is along the east and west axis with the long facades of the building along the north and south.

However, site constraints such as topography, surrounding buildings, streets, etc. can conflict with wind direction and may not favor this type of orientation for the wall as well as windows. This can result in major openings being exposed to direct solar radiation; hence, there is a need for solar protection. If we look at solar protection, the three main types of protection are the horizontal shading device, the vertical shading device, and a combination of both, apart from having external screens and internal screens. The opening size, the opening position, and the shading device—all three in combination—play an important role in reducing the heat gain inside.

In this class and the previous class, we have seen how the size of the opening, the location of the opening, and the shading device play an important role in reducing energy consumption for heating or cooling. With this, we will stop today's class, and we will continue the next class with another passive design technique. Thank you.