

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

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Lecture 03

High

Performance

Glazing

Hello everyone, so in our last class we saw an advanced passive technique called roof pond treatment. Today we will have a look at another advanced passive strategy, and today we will look at high-performance glazing. Now, a high-performance window is one that provides ideal visual and thermal comfort for those inhabiting the associated room while also reducing the amount of non-regenerative energy required by the building. Given its position in the building envelope, separating the external from the inside, it is obvious that the window must have features that are suited to the prevailing conditions, both climatic and in terms of building properties and usage. A wide variety of high-performance windows are already available on the market, and more are being developed because of the need for using them in energy-intensive buildings. So, if you look at how high-performance glazing is classified, we have ordinary glass, which is called clear glass.

The classification of glasses- first you have clear glass and then the second classification is the tinted glass or rather. The clear glass can be used as a base case and tinted glass is the first classification. Then there are reflective glasses. Reflective glasses can be hard coat or soft coat, and both of them are actually high-performance glass. Then we have lacquered glass, the frosted glass, and a mirror.

This is the very broad classification of glass. And by adding any single element to this, the entire property of the glass can be changed. So, by tinting the glass with various materials or various metals, the property of the glass can be changed, and that is true for the other type of classification also. Let us now look at the working principle of high-performance glass. So, the principles are basically conduction; what happens is heat transmission happens via the substance.

So, suppose we have double glazing glass. Even through the double-glazing glass, conduction does happen. The quantity of conduction is less because double glazing reduces conduction by placing insulating air or gas between the glass. Then heat gain happens due

to convection because air is a fluid. So, double glazing with a sealed gap lowers convective heat transmission.

Then there is radiation - Low-E coatings on double glazing deflect infrared radiation, keeping the inside temperature stable. Then there is reduced condensation. Double glazing reduces condensation while preserving a warmer interior glass surface. So, what glass does with solar energy? What glass does is, when light strikes on the glass, when we have double glazing, a part of infrared radiation is transmitted inside, but a major part of infrared radiation is reflected. So, glass does primarily three things.

It reflects, it absorbs, and it transmits. So, part of it is transmitted, a part of it is absorbed, and a part of it is reflected. Similarly, for visible and ultraviolet light, solar control low-e glass is designed to transmit a high amount of visible light and reflect more infrared light. Whereas passive solar e-glasses are designed to transmit high levels of both infrared and visible light. And reflective coated glasses generally reflect the most visible light.

Let us look at some of the technical properties of windows. First is thermal transmittance or U-value. This is one of the primary roles of a window which is to restrict heat transmission between interior and outside. Therefore, providing adequate thermal insulation. The thermal transmittance or U value quantifies the rate of heat movement per unit area per degree of temperature difference between within and outside.

It is measured in watts per meter square Kelvin. The U value of glass is the value of the center of the glazing not the entire window. So, UW value includes the impact of the frame and the glazing edge. Then we look at the total solar energy transmittance also known as solar heat gain coefficient or SHGC or the sun factor. This is also called as the G value.

The G value is mostly for transparent components like glazing. It is defined as the ratio of solar heat intake via the window and the solar radiation impacting the exterior surface. The total solar energy transmittance includes both the solar radiation transmitted by the glazing unit and the percentage of solar energy absorbed in the glazing and transferred as heat to the interior environment. The optimal G value for a window is high enough to allow solar radiation in winter and low enough to prevent overheating in summer. Glazing with G value less than about 0.5 is commonly referred to as solar control glazing since it is designed for conditions with copious sun radiation that has to be managed to minimize overheating concerns. The third technical property is the visible transmittance. Now visible transmittance is defined as the ratio of light transmitted by the glazing to the light incident on the glazing. A higher value of visible transmittance is desirable generally leading to more daylight indoors and associated psychological benefits. A low value may need to be chosen in specific cases.

For example, if the contrast becomes too great for work with computer monitors. Values for up to 0.81 or 81% can be obtained for high performance glazing. Next, we will see the types of high-performance glazing. First are static glazing technologies.

Now, a single pane of glass that is 4 millimeters thick has a U value of 5.8 watts per meter squared Kelvin. Increasing the thickness of a single glass pane does not have a significant effect on the U value. A 10-millimeter pane still has a value of 5.6 watts per meter squared Kelvin.

A significant reduction in the U value of glass panes was found for glass samples with thickness above 12 millimeters. So, only above 12 millimeters, there is a significant difference. However, the reduction in the heat transfer comes with a penalty in the visible transmittance and the overall weight of the window. Let us now see the types of high-performance glazing with respect to multi-pane glazing. So, double-glazed windows have been commonly made in the United Kingdom since the final part of the 20th century.

Today it is available in most parts of the world. By employing the space between panes as a thermal barrier, they help to minimize energy consumption in buildings while also boosting material insulation capabilities. There are four distinct configurations of double-glazed panes on an air gap. Including transparent, absorbent, low-E, and reflecting glass. Reflective glass in particular has the ability to save up to 72.9% of energy use. Which equates to a 50% decrease in heat losses over single glazing. Double-glazed windows have a 2.5-times lower heat transfer rate. than single-glazed windows, resulting in a 50 to 67 percent reduction in heat input in warm areas. Next, we will see multi-pane glazing.

So, the double glazing is a more effective reduction. The insulating effect of a 16 mm air gap approximately halves the U value to 2.6 watts per meter square Kelvin. A truly high-performance glazing is constructed with an almost invisible thin silver coating on one of the gap-facing glass surfaces to reduce radiative heat loss. Then a gas-filled double glazing with argon suppresses heat transfer by convection and gas conduction.

This also achieves a U value of 1.2 watts per meter squared Kelvin. Triple glazing is added for further panes, and that is with a low-emissivity silver coating filling the gap with krypton instead of argon, and the U value can go even up to 0.5 watts per meter square Kelvin.

So, double glazing gives 2.6, then with silver coating 1.2, and triple glazing with silver coating 0.5. So, the more layers you add with research, the better the performance can be. The third type of glass we will see is the tinted glass.

So tinting glazing paint maintains the material transparency from the inside layer of the window. It entails adding metallic components to the glass floating process. This technique lowers window transmittance, visibility, and color while absorbing some solar heat and blocking the sunlight. It maximizes solar energy absorption by up to 50% for single panels, decreasing the glare. This table summarizes the tinting glass options in the market, and this is organized by color and thickness with matching levels of transparency, insulation, and heat gain coefficient.

So, a 4 mm glass that is tinted with bronze has a U value of 5.8. The same is true for green tint and grey tint. But the G value changes between the bronze-tinted and the gray-tinted glass and also between the gray-tinted glass. The visible transmittance also changes when the colour of the tint changes.

Then the fourth is thermally insulating or low-E or low-emissivity glazing. Thermally insulating or low-E or low-emissivity glazing is the most common form of high-performance thermally insulated glazing. It refers to the property of the thin silver coating on at least one side of the glass surface that results in strong reflection of infrared radiation or heat. This coating is applied to the gap-facing side of the interior glass of insulating glazing units, which are designed for colder climates to reflect as much room heat as possible back into the building. To guarantee that as much solar radiation as possible passes through the glazing into the room, the silver film is sandwiched between thin dielectric films that minimize the coated glass.

Its reflectance is changed in the solar spectral region. Thus, a high G of 0.64 and thermal transmittance values of 0.81 combined with the U value of 1.2 watts per meter square kelvin for a 4 mm glass and 16 mm cavity filled with argon can be obtained.

The fifth one is anti-reflective coating. Anti-reflective coatings are a new approach for increasing daylight transmittance in windows. These coatings can improve apparent transmittance by up to 15%, particularly in double-pane windows. The implementation of this technology has resulted in a 4% reduction in yearly heating consumption. This table here summarizes the technical data on this glass and the values that it can produce and give.

You can see how this glass just because We use a combination of anti-reflective low iron glass filled with argon in the cavity and having a solar control film gives a U value of 1.2. The same with the low E coating gives a 1.2 as against 5.

8 for an anti-reflective low iron glass. Sixth is a self-cleansing coating given to glass. Self-cleaning coatings employed on glass is a labor saving approach and water saving approach

to clean glazing components. Commercially self-cleaning coatings are classified into two types: hydrophobic and hydrophilic. Hydrophobic coatings induce water droplets to roll on the glass surface due to the high static contact angle obtained by molded polymers, waxes, and chemical vapor deposition. Hydrophilic coatings use a thin, transparent layer of titanium dioxide to provide a static contact angle of less than 90 degrees between glass and water.

When exposed to light, the hydrophilic coating employs a photocatalysis process to chemically break away glazed debris. Normally, for nanocoated self-cleaning glass, titanium dioxide is used, and what it does is, in the presence of dust, it combines together the dust particles along with the water and slides down, and because of this use of this glass, a lot of economic savings is done, especially for glasses of high-rise skyscrapers where otherwise humans have to be employed to clean the glass from outside. Next is vacuum glazing. This is seen as a potential approach for decreasing heat transmission by air conduction and convection within the evacuated gap. The reduction in gas particles in the evacuated gap improves the efficiency of vacuum glazing.

Commercially available vacuum windows can have U values as low as 0.7 watts per square kelvin. Aerogel, a highly insulating substance made of 4% silica and 96% air, has a foam-like molecular structure that resists heat convection while providing great light transmission. The use of aerogel in the window business has shown a considerable decrease in heat transmission by conduction with U values as low as 0.05 watts per meter square Kelvin in the material characteristics alone.

Let us now look at the types of high-performance glazing with respect to dynamic glazing technologies. So dynamic windows involve fenestrations with movable or switchable devices for shading and energy harvesting. Variable optical and thermal properties are a key feature often dependent on climate conditions, such as smart windows. This table summarizes the properties and characteristics of some of the dynamic glazing windows. So when electrochromic glass is used, liquid crystal droplets in a conductive glass are used.

This requires constant energy to maintain a clear state. It uses dynamic control, and it requires constant energy to maintain a clear state. Whereas photochromic glass has polymeric matrices and blocks sunlight as in response to a natural light incidence. Thermochromic glass uses vanadium dioxide to change its opacity.

It acts more like a polymer film. The transmittance gets reduced when exposed to higher temperatures. Then we have the gasochromic glass, which uses tungsten dioxide in gas-encapsulated molecules. This regulates transparency in variation to outdoor temperatures. Here is an example of what an electrochromic glass could do: how the liquid crystal

droplets in a conductive glass change the visual transmittance. Or photochromic glass will react as the outside temperature increases; it blocks the sunlight, as shown here in the picture at 1 pm.

And this is the example of a thermochromic glass, which again changes its visual transmittance when exposed to higher temperatures. Let us now look at the types of high-performance glazing with respect to dynamic glazing technologies. We will see the PCM windows. Phase-change materials, or PCMs, absorb, store, and release energy from the surroundings. The use of PCMs in windows is critical for decreasing heat transmission, as demonstrated by their structure.

Recent research suggests that double-glazed windows with PCM filling can reduce solar heat gains in buildings. The usage of PCM in windows can also increase the temperature of the window's inside surface by up to 3 degrees Celsius. Second is building integrated photovoltaics. So, this tackles the difficulty of maintaining high electrical production while without reducing visual transmittance in windows. Novel improvements in PV glazing are frequently confined to semi-transparent PV cells.

Dysensitized solar cells employed titanium dioxide film to achieve an average energy efficiency of 16 to 20 percent. Recent window technologies concentrate on capturing solar energy for electrical conversion, resulting in less environmental impact, lower cost, and more efficient land use. Let us now quickly look at some of the buildings where high-performance glazing is used in India. I am not looking at these as case studies and getting into the details of the properties of the glass used in each of these because we have covered the properties of glass quite extensively. And this is only to give you a perspective in case you happen to visit these buildings.

One is the CII Saurabhji Godrej Green Business Centre at Hyderabad, the Technopolis at Chennai, Bipro Technologies at Gurgaon, the Olympia Tech Park Chennai, and the Grundfos Pumps India Private Limited Chennai. All of these buildings are green-rated buildings, and one major reason for their energy efficiency is also the use of glass, apart from the other passive techniques these buildings have adopted. Next, we will see the case study of Olympia Tech Park, which is in a warm, humid climate. It is in Chennai, and it has used high-performance glazing, which has effected better heat insulation of the window, which results in reduced HVAC loads.

It enhances available sunlight without allowing excess heat gain. It optimizes solar heat ingress into the building, resulting in reduced HVAC load. The overall window wall ratio for the building is 27% against 50% of a conventional building. Another case study, and most of the glazing area is on the north facade of the building. The shading coefficient and

light transmittance of 23% for the glass were developed carefully in order to enhance available daylight in the space and maintain visual comfort for the occupants without compromising on energy efficiency.

The other performance parameters are listed in the table adjoining it. Then next is the availability of material. Not yet locally manufactured by the Indian glass industry, the project had to resort to importing high-performance glass. This resulted in difficulty to repair or replace failed components during the building's operation. So large stocks of spares were needed to maintain, resulting in high inventory costs.

This figure provides a market-based summary of fenestration technologies emphasizing U-values from major international window companies driven by efforts to minimize conduction and radiation and glazing samples. Electrochromic, substitute glass, and vacuum-closing windows show significant reductions in heat transfer. Less the U-value, less is the heat loss. So, in conclusion, energy loss through the building envelope is caused by the interaction of external surfaces with the surrounding environment. Traditional windows have significant heat transmission rates, particularly in u values, when compared to walls roofs and floors the goal of this lecture is to limit heat transmission in windows utilizing static and dynamic technologies. Increasing the thickness of window panes is not cost-effective as it makes samples heavier and bulkier. Tinted windows have an impact on apparent transmittance and the solar heat transfer coefficient but have little effect on heat transmission.

Low-E anti-reflective and self-cleaning window coatings effectively lower the solar heat gain coefficients. Gas-filled cavities like argon, krypton, and xenon have much lower U values than air-filled cavities. Multi-pane glass, particularly vacuum glazing, greatly minimizes heat transmission compared to normal double glazing. Dynamic windows provide control over visual transmittance and heat transfer. Nevertheless, manufacturing process, market availability, and weather conditions dominate its use.

Building integrated photovoltaic modules offers potential for energy collection with minimal impact on window lifespan. Vacuum glazing technologies with aerogel applications and semi-transparent crystalline PV modules are the most efficient, helping to achieve net-zero carbon buildings. So with this, we have covered this high-performance glazing quite extensively. and using it as an advanced passive technique. We will stop today's class with this, and we will meet next class with another lecture on advanced passive techniques.