**Building Materials And Composites**
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**Lecture – 12**
**Types of Glass**

In this lecture 2 of module 3, we will elaborate on the various types of glass, which are essential knowledge for architects.

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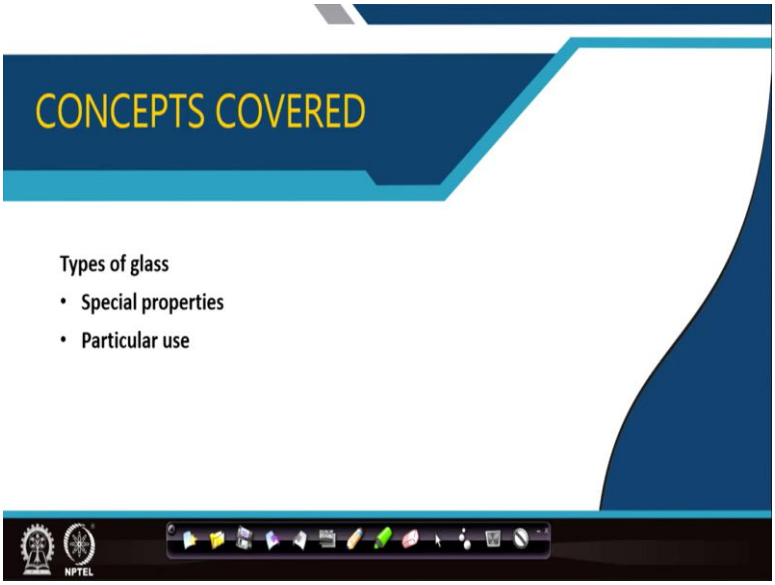


Here, we will discuss the types of glass, their special properties, and uses, such that you can recommend the appropriate glass type based on a specific use-case. Mostly, you will see plate glass, sheet glass, float glass in buildings, all of which were mentioned in the earlier lecture. The other specific types of glasses are required only when we have a distinctive use-case.

You may have an entire building façade made of glass. The entry for a shopping mall may be of glass, or say, in an office, the interior partition walls are made of glass. In a restaurant, glass wall partitions may be made between the dining tables. You cannot generalize the same type of glass for all applications alike. Here we will explore the individual glass types meant for specific uses, the methods for their manufacture, their characteristic features, and typical uses.

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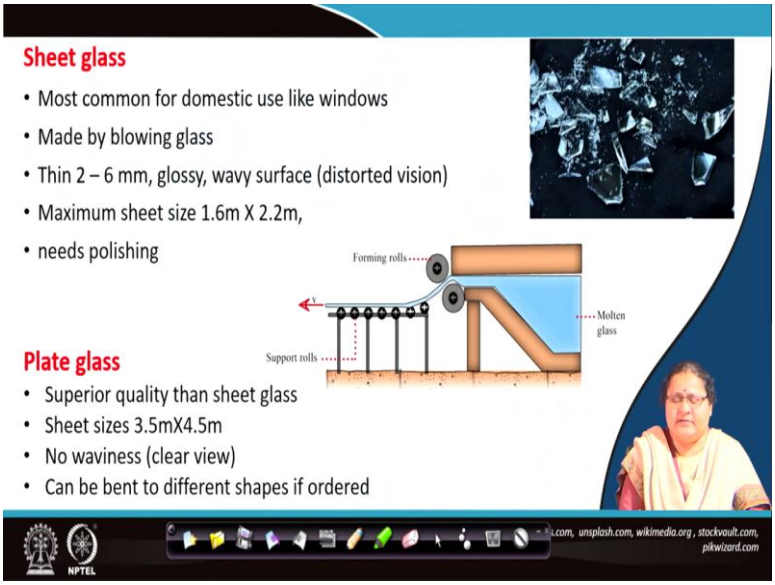


We will start with sheet glass, which is the most common of them all, domestically very popular as glass window panes. These are made by blowing glass. You may recall that glass is blown into thin (2 to 6 mm thickness) sheets, having a glossy surface. If the glass is not uniformly cooled, the final surface may be wavy. You may find some distortion in vision when looking through such a glass.

You may not clearly identify someone or something on the other side of the sheet glass due to this waviness, typical of sheet glass. Sometimes, air bubbles may remain entrapped in the glass during the blowing stage. The sheet sizes can be a maximum of 1.6 m × 2.2 m, which is almost 5’ × 7’ (feet). Sheet glass needs polishing. Once it breaks, it will shatter into small sharp-edged pieces (shards), which poses a risk of severe injuries if not carefully handled.

Plate glass is of comparatively superior in quality than sheet glass. Their sizes are relatively larger, 3.5 m × 4.5 m, and not produced by blowing; instead, they are manufactured as rolled-out sheets. Due to this gradual roll-out, no waviness is formed. Plate glass may be bent into any desired custom shape according to requirement (customer’s order). We will discuss how the glass is made. The details of the rolling operation are given below.

The “forming rolls” on the two sides help the glass sheet to form, and the gap between the rolls maintains a uniform thickness for the sheet. The multiple support rollers allow the glass sheet to move forward. As the sheet moves outside, it gradually cools down. In the furnace (towards the right side of the figure), the molten glass is filled to the brim, which basically comes out to ultimately form the sheet.

In this process, the sheet size limit can be up to 4.5 m in length and 3.5 m in width, and there is no waviness generated. The support rolls gradually move, and the glass sheet gets cooler as it passes on them. If it has to be bend as per customers' requirement, the shaping should be done before the cooling stage, while the glass still in its unset form.

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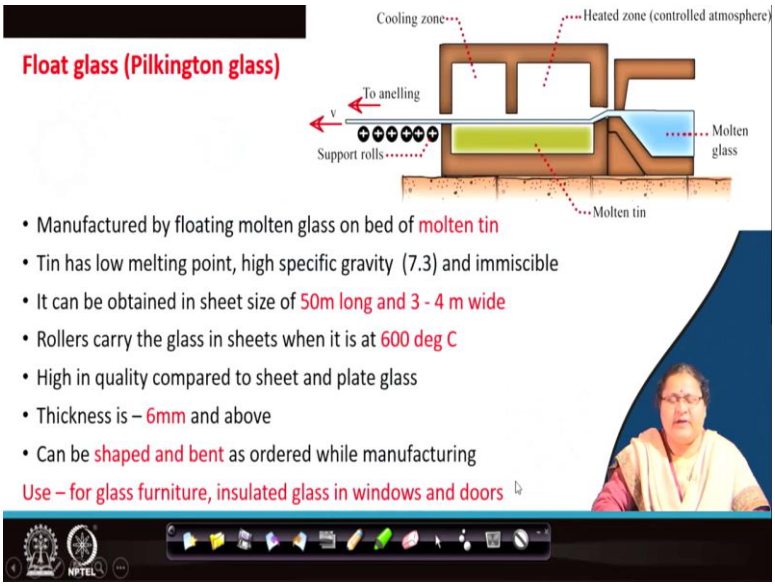


Next is the float glass. It was invented by Sir Alastair Pilkington (a British engineer and scientist). We will see the fundamental differences between a float glass and plate glass. Here too, there is molten glass- this passes on top of the molten tin. Tin has a higher specific gravity (7.3) and a low melting point compared to glass. Since glass has a lower specific gravity (2.5) than tin, it will float on top of the molten tin.

So, gradually, the glass sheet will come out, gradually moving on top of the support rolls. It will get cooler as it comes out. All of the processes happen in a controlled environment, and the product is called Pilkington glass. Also, since it floats over the tin, it is also called float glass. One unique feature here is that float glasses can be obtained in sheets of 50 m (long) × 3-4 m (wide). The rollers carry it when it is at 600°C, and the glass gradually sets while cooling down.

Float glass is of higher quality than both sheet and plate glass. It does not require polishing. They are obtained in thicknesses of 6 mm and above, are rigid, and have slightly higher strength than plate glass. Float glass can be custom-shaped (bent) as desired, but only during

manufacture. This type of glass finds applications in glass furniture, insulated glass glazings in windows and doors, shop (showroom) shelves, and tabletops.

Float glass is relatively rigid and can sustain a bit heavier load than both sheet glass and plate glass.

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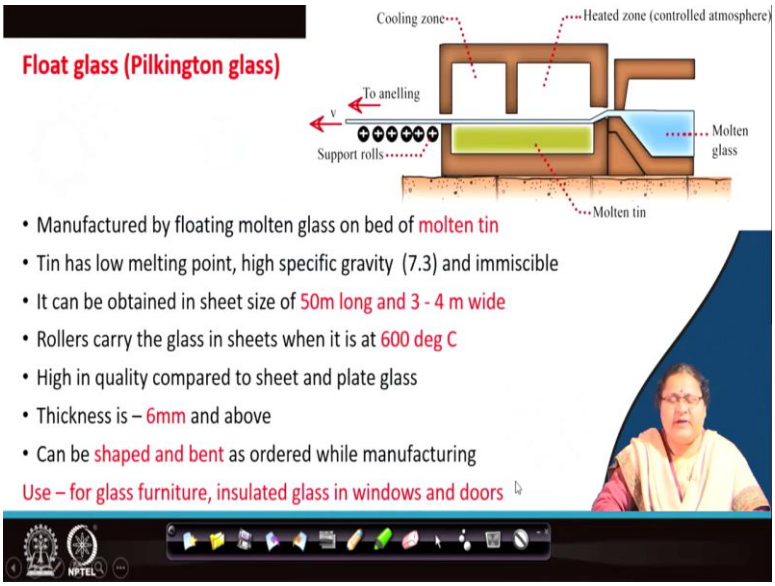


Let us discuss another type of glass called ‘wired glass’. At the stage of formation, during the manufacture of float glass at 600°C, and before it gradually cools, an iron wire mesh can be put (or ‘impregnated’) inside it. Since the glass has not yet set at this high temperature (600°C), the mesh reinforces the glass. Such a type of glass is called ‘wired glass’.

The specialty of wired glass is that unlike other glasses (which shatter and fall in sharp wedge-like pieces), here, the broken pieces are held together by the wire mesh. Even if some of the glass pieces fall, the broken parts will not have sharp edges. Thus, these type of glass s preferred in skylights or high-level windows, atriums, and industrial buildings, which do not need to be accessed frequently.

Hence, even if the glass breaks due to gusty winds, storms, or thunder, it would not shatter and fall like the other glass types. The wire reinforcement holds it together. The wires are 0.5 mm in diameter, and the thickness of the glass is around 5-7 mm to accommodate the wires. Due to this fact, wired glass is generally heavier.

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Next is frosted glass, which is also available in the market under various names- ground glass, translucent glass, or patterned glass. This type of glass is obtained by sandblasting or acid-etching on plate glass. Sandblasting is a process in which fine sand particles are hit at high velocities onto the surface of the glass. This erodes ("eats away") some portion of the glass, giving it an obscure look.

Hence, the glass loses its' shine and becomes translucent. Light falling on the surface refracts only partially (entire light does not pass). Therefore, although you can see diffused shapes, you cannot distinctly identify any object that lies behind the glass. Due to this semi-opacity, frosted glass is good at providing visual privacy, simultaneously maintaining a formal environment, such as office interiors.

For example, in the manager's room in an office, obscure glass is used at eye level. Hence, although you can check if the manager is inside the cabin or not, you cannot distinctly identify him/her from the other side. There can be no direct eye contact, and thus the manager is not distracted by people moving around. Similar, translucent (frosted) glasses are used in interior partitions in restaurants, washrooms to maintain visual privacy.

These glasses are basically plate glass, sandblasted, and acid-etched. The acid-etching helps in creating aesthetically pleasing artwork patterns on the glass surface, say, by keeping a part as groud/ frosted (translucent) and other parts transparent.

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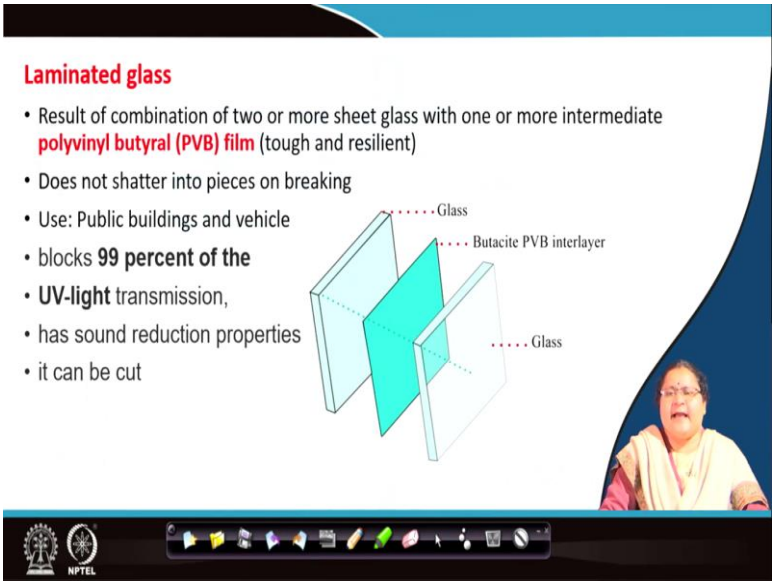


Another type of glass is laminated glass. Here, too, if the glass breaks, it does not shatter or fall down like plate glass. The term 'laminated' is due to the presence of an intermediate lamina between the two glass sheets. So, there are two glass sheets and an intermediate layer that is made of polyvinyl butyral or (PVB). This layer is transparent, tough, and resilient- and holds the two glass pieces together.

Even after these glass pieces are attached together, it is difficult to identify the middle layer, which helps the product retain its see-through properties. Since the glass has been strengthened, it will not easily break, and even if it breaks on impact force, the broken parts will remain stuck to the PVB lamina that is present between the two layers. The middle layer helps to block ultraviolet radiation and also makes it soundproof.

This type of glass is mostly found in the automobile industry. In the domain of building construction, laminated glass is used in tall buildings, which helps in entrapping solar energy. They are used to block the UV rays from entering the interior. You will find them in public buildings, high-rise residential buildings, etc. As you have seen, the two positive points here are that it does not shatter (or fall) on breaking and also helps minimize ultraviolet radiation.

Considering these two potential applications, you can use laminated glass in a building.

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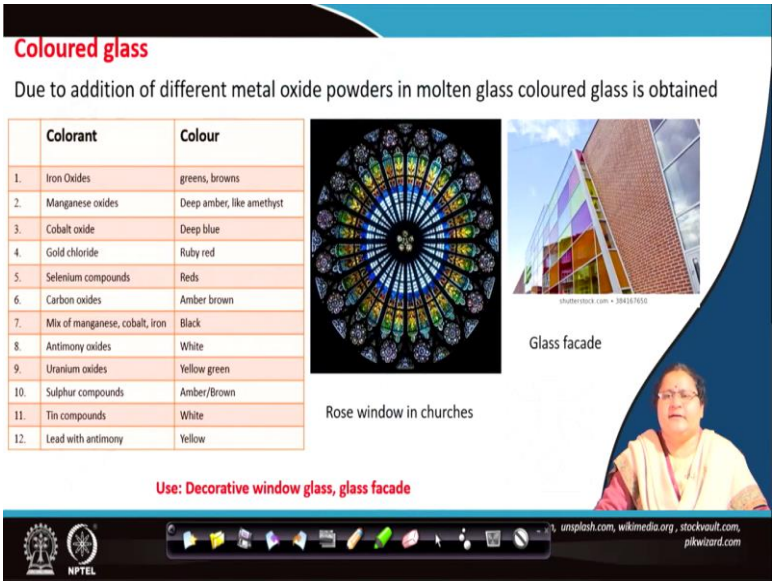


Another type of glass is colored glass. As already told, this is made by adding different metal oxide powders in molten glass. It should be planned beforehand. When the glass is being manufactured, the metal oxide corresponding to the desired color must be put into the mixture (viscous liquid) so that the final product becomes colored accordingly. In this picture (see image in slide), you can see the rose window of an old church. The use of colored glass is a very old concept- the applications can be found in several ancient buildings.

In the other picture (see image in slide), the facade is made entirely of colored glass. This emphasizes the look of the entrance area. A list of colorants and the corresponding color is given. Iron oxides (ferrous and ferric) impart a green and brown color to the glass. As you already know, greenish tint is naturally occurring in glass (due to iron oxides in the sand). Manganese oxide gives a deep yellow color (like amethyst).

Cobalt imparts deep blue color. Gold chloride imparts a ruby-red color. Selenium compounds give reds. Carbon oxides give amber brown. A mix of manganese, cobalt, and iron will impart black color. Antimony oxides give a white color. Adding uranium oxides will give a yellowish-green color. Sulphur compounds give an amber or brown color. Tin compounds impart white. Lead mixed with antimony impart a yellow color. As you can see, most coloring agents are metal oxides, and some are metal chlorides. These are added to the mix during the melting process to impart the desired color to the glass.

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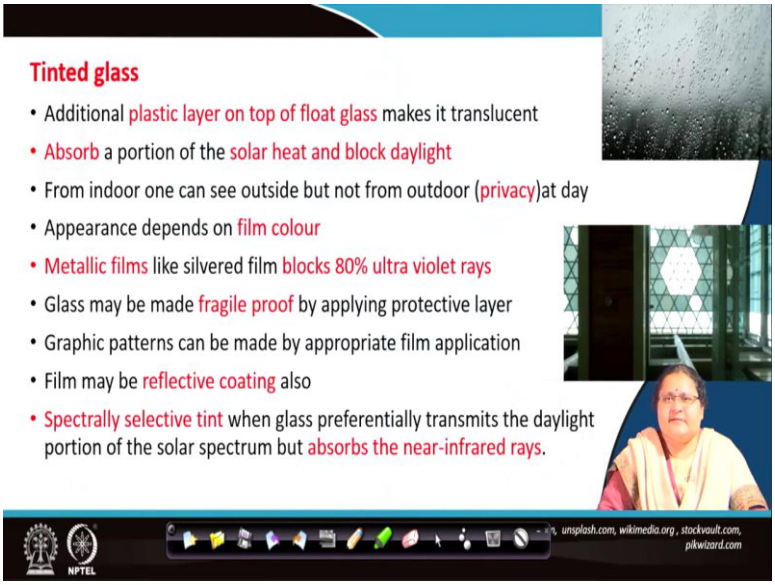


Another type of glass is ‘tinted glass’. This is obtained by sticking an additional plastic layer on the top surface of float glass or plate glass wall, making the overall product translucent. As you can see, such an application does not need to be specifically planned beforehand. Even after the glass is manufactured, you may later desire to have a specific pattern or tint, and accordingly, a plastic layer is pasted on top, creating such a pattern on the facade.

Due to the plastic layer, it will absorb (and hence, block) a portion of the solar rays. So, the entire daylight (100%) would not enter indoors. During the daytime, you can see the outer scenery from the room interior through this glass, but from the outside, no one can have a glimpse of the interiors. At night, however, it becomes difficult to see in both directions. Thus, tinted glass is good at providing privacy.

The appearance of the tinted glass depends on the color of the coating (plastic layer/ sheet) on top of it. Depending on the type of film chosen, some desired effects may be achieved. For example, putting a silver film will block 80% of the ultraviolet rays. In hot places that receive large quantities of solar radiation, the application of the tint on the glass surface will help in improving the energy performance of the building.

This kind of film that reflects the solar radiation outside is suggested only in case if the glass itself has any inefficiency. Adding this film makes it less fragile (less brittle). So, if there is any chance that the glass may break due to any impact force, the tint applied to it will prevent the breakage. You may have interesting graphic patterns with this film to avoid a monotonous glass façade design.

Variations in tint, graphic patterns, etc., may be developed. It may be a reflective coating if desired. You may also put a spectrally-selective tint (layer) that only allows specific wavelengths of light to penetrate inside the glass- while absorbing the near-infrared rays. These are protective coatings that block harmful radiation from impacting the interior environment.

Here, you are protecting the building interior from the external solar radiation. It blocks around 80% of the ultraviolet rays; the near-infrared rays are absorbed. The spectrally-selective tint only allows the visible portion of the spectrum to enter the interior space.

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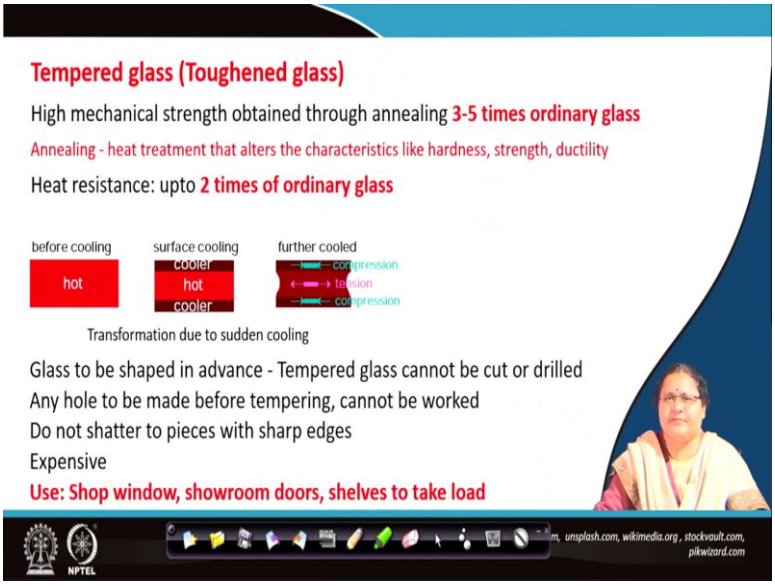


After discussing the different types of glass, such as sheet glass, plate glass, and float glass, we now come to another variety called tempered glass. You will find glass facades, walls, and entrance lobbies entirely built of glass in modern showrooms, jewelry shops, etc. Even the main shutter door at the entrance is mostly made of glass. Think about how do the shop owners assure themselves of security in case of a burglary, particularly at night.

Although the glass facade may appear vulnerable, in reality, the glass is much tough and durable to provide sufficient protection from break-ins. They are at least three to five times stronger than ordinary glass. The strength is achieved by a process called ‘annealing’, which is basically heating followed by gradual cooling. This alters the hardness, strength, and ductility of the glass. As you can see in this diagram (see video), before the cooling stage, the

entire product is hot. When the cooling starts, the glass surface cools faster, whereas the internal part still remains hotter.

When further cooled, the upper surfaces get closer to each other and compressed, whereas the internal portion is still in its hot liquid form. On the upper (surface) layers, glass in its amorphous form and is under compression. The inner part is under tension. The sudden cooling changes the material properties of the glass, giving it a heat resistance of at least two times higher than that of ordinary glass.

Unlike the other types of glass where shaping, drilling, cutting, or welding were possible even after installation, they are not feasible for tempered glass. Any desired drilling or cutting must be done at the formation stage, much before the tempering stage.

Thus, if you need any kind of custom shaping, or any holes for attachment of screws, etc., the shaping has to be done at the ‘float glass’ stage (during manufacture). Thus, tempered glass is basically float glass treated by the process of annealing, which helps it gain strength and heat resistance. This type of glass is preferred in showrooms, shop windows, load-bearing shelves, facades, entrance lobby, etc.

Tempered glass is expensive, tough, and does not break easily. Even if it breaks, it will crumble to crystals (akin to sugar crystals), as can be seen in the picture (see image in video). The edges of the broken chunks are small and blunt- that does not pose a risk of injury, which is the main specialty of this glass. As you can understand, tempered glass is mainly used as a replacement for non-load-bearing walls.

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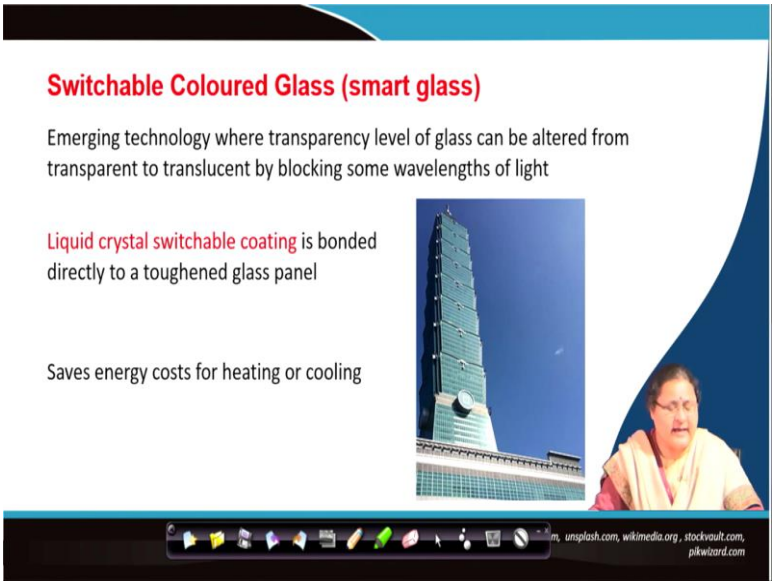


Our next topic is switchable colored glass, which s also called ‘smart glass’. This is very common in airplane windows. If you are flying at a high altitude, sometimes you may not want the sunrays to enter inside. There are specialized mechanisms that can change the color of the glass at the press of a button. Emerging technologies have nowadays made it possible to have spectacles with photochromatic lenses- where the transparency level of the glass is automatically altered from transparent to translucent to fully opaque.

This is achieved by blocking some wavelengths of light from penetrating the glass. The glass has a liquid crystal switchable coating that is bonded directly to the toughened (or tempered) glass and keeps on changing the transparency label from time to time (based on current temperature or light level), hence the name ‘smart’ glass. Thus this can save energy costs for heating or cooling, as per immediate requirement.

Thus, we can effectively regulate the quantity of sunlight to be filtered into the interior space. I had already listed hydrophilic and hydrophobic glass in the list for various glass types, but we will discuss that topic later. Here, there is a photograph of the application of the switchable glass in the Taipei-101 building. The entire façade is a vast expanse of glass, fully coated with this switchable liquid crystal layer. This technology has been found to immensely contribute to energy savings by changing the allowance of solar radiation to the building interior.

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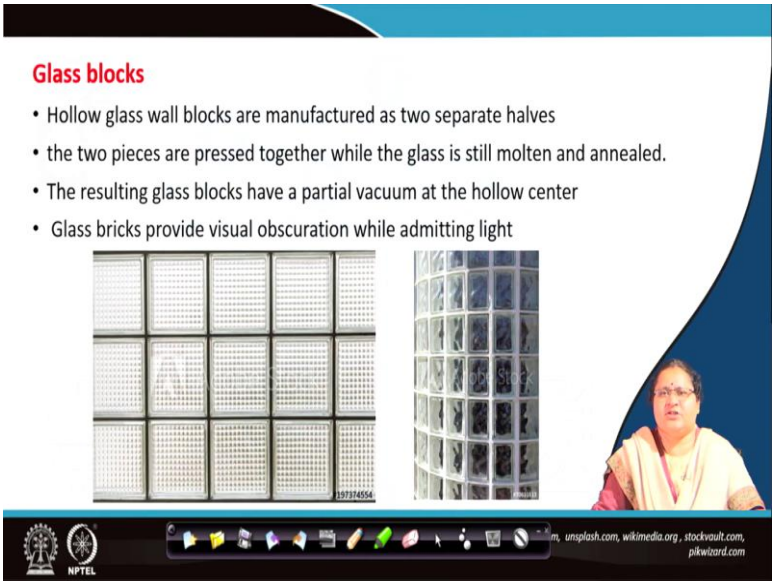


Glass blocks are another application of tempered glass. Two pieces of tempered glass are moulded and pressed (joined) together to make a glass block. In the process, the air gets entrapped in between, which acts as an insulator. Hence, even though it is glass, and you can still partially see through it, the images are blurred and obscured, providing visual privacy. Thus, it will admit some portion of the light, yet, you cannot fully recognize an object or person on the other side.

This is again another case of tempered glasses being converted into such glass blocks, and two such parts are fixed to form a single block. We will cover the details later.

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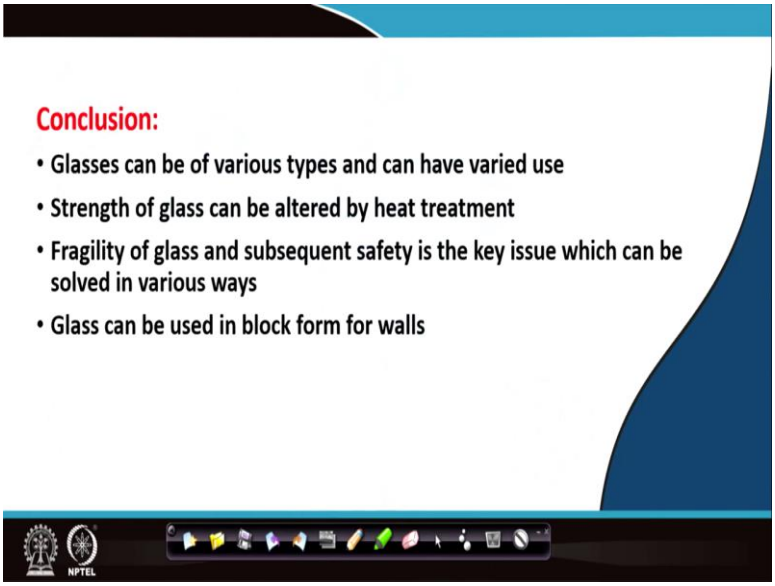


So, in this lecture, we have explored several types of glass and their variety of uses. The strength of glass can be altered by heat treatment. Different glass types may be produced by -

either inserting a lamina in between two layers, or putting a tint on top of the glass, or creating graphics (artwork) on top of it. The fragility of glass and subsequent safety are crucial issues in the usage of glass that can be addressed in various ways. Glass can also be used in block form for walls. I end today's lecture here, and we will now move to the third lecture of this module, where we will learn about fixing glass in a system. Thank you.