Building Materials and Composites

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Lecture - 11
Glass

Today we are going to start module 3. So, Module 3 is about glass and ceramics. You always see glass around you. And you already know that it gives transparency to a building. You can see through it across to the other side. You are aware of the most popular applications of glass - on windows and sometimes doors. There are many other uses which we will discuss gradually.

But what is the more critical property in glass (as compared to other materials) is its transparency; it connects you with the outdoor when you are indoor. At the same time, it connects you to the indoor when you are outdoor. This is also the beauty of glass which you may not find in almost all other materials. Another challenging property of glass is its’ brittleness. Whenever we come across a glass item, we always remain alert that we have to handle it with care because it is brittle and may break.

So, any kind of uneven treatment (or any impact force) to the surface of the glass may cause it to break. Along with glass, we will also discuss ceramics, particularly ceramic tiles, which we use on floors as well as on walls. It has a coat of glass that imparts the ceramic property. Another crucial property of glass and ceramics is they are very much inert towards chemical action.

Glass has specific uses, and we have to take care of this brittleness factor depending upon the type of usage, so that it has a prolonged life. Similarly, ceramics also have particular applications- mostly in clinical, chemical, or biologically safe environments.

Also, there are ceramic tiles that have replaced stone, marble, granite as building materials. A higher version of ceramic tiles are the vitrified tiles.

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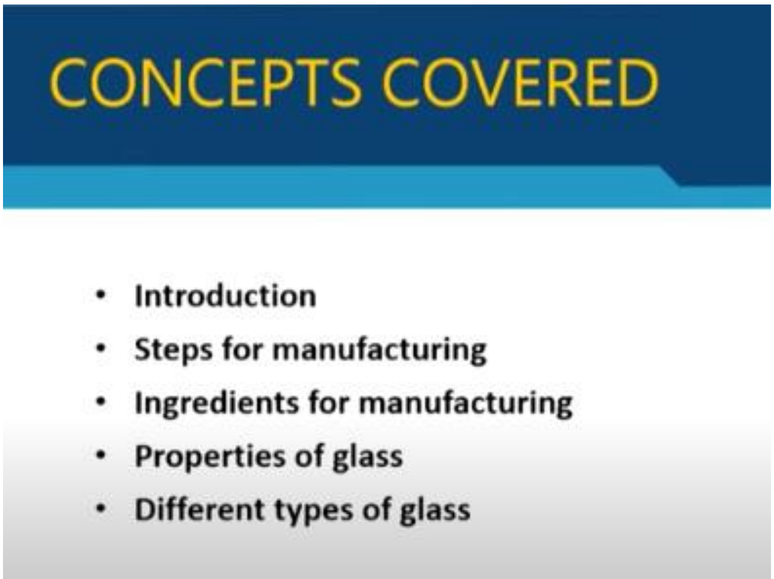

So, we will discuss a small introduction on glass, followed by steps of its manufacturing and the ingredients necessary for it, the properties of glass, and also a list of different types of glass, which we will elaborate it in our next lecture.

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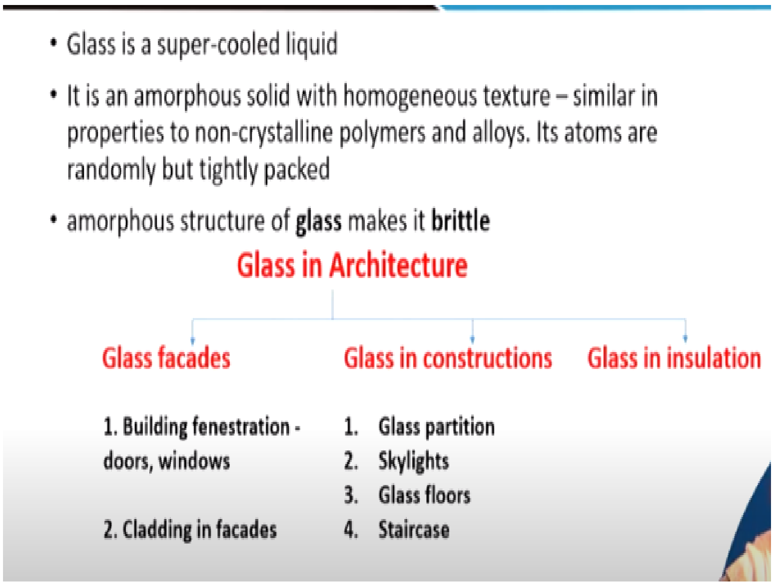

Glass is a super-cooled liquid, amorphous in form. It does not form crystals. It does not make crystal formation but has random and tightly packed atoms, and it is this structure that makes it brittle. It breaks easily because the bonding does not occur as a crystalline structure, and it is homogeneous in texture. As you know, glass is transparent.

Thus, any kind of impurity in it would be visible. If there is an air bubble entrapped while the glass is being made, then it will be visible. If, say, a small stone or any foreign particle or metallic particle remains embedded in it, that will be visible by naked eyes. Hence, you need to produce clear glass. You also expect the glass to be perfectly flat. If you hold a glass piece horizontally, and you look at it along its horizon (directly parallel to its surface), you may find it is a bit wavy.

So, when something is on the other side of the glass, the image may not be properly seen. The waviness in glass can also be tested. Glass in architecture is mostly seen in three areas- glass in facades, glass as a construction material, and glass in insulation. In facades, you would find its application in the building fenestration (that is, the doors and windows), and also the claddings in facades.

There may exist glass walls, where adjacent glasses are fixed, creating the glass facade. Glass may also be found as a partition wall. It comes in the form of glass blocks too. Another application is in skylights. Say there is a space (such as an atrium) that has a roof. To provide appropriate natural light access, you have to create an opening on the high ceiling and cover it with glass, which is called "skylight". Solar rays enter filtered into that space and provide natural lighting.

We may have glass floors, where transparency allows us to look at what is happening on the upper or lower floor. This gives a sense of transparency, and you can see the entire space at a time. As a construction material, glass staircases are very popular, provides a transparent look compared to brick or stone staircases. These are the important application areas of glass.

But as you know, glass is brittle. However, there are different types (specially treated) of glass that helps in developing special qualities like the ability to support loads or being less brittle, or being more safer when broken. We will discuss how those properties are achieved and what are the appropriate glass types to be proposed for specific application areas.

With all those unique qualities, the price of glass increases. There exist glass for insulation (glass wool), which are basically threads or strands of glass used as insulators. We will discuss that topic later.

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Here, you see the use of glass for viewing, for example, glass pane in windows- they are crystal clear (you can easily see the outside scenery from inside). We can also use glass as a shelf- they are popular in showrooms, shops (for example, in small grocery shops- glass top counter, you can easily see the display area below counter). The shopkeeper puts glass as the top below which he actually displays his items on glass shelves.

You can have glass as a guard wall. Instead of having a conventional railing, it creates a transparent barrier, through which one can see what is happening below (or on the other side)- the primary function is to guard the place. No one would usually push the guard wall, but at the same time, if something hits on it, it would not fall or break. In a strengthened glass, a mesh is provided inside the glass, which provides reinforcement to the glass.

If this glass somehow breaks, a certain characteristic effect will occur, which we will discuss later. Here, you can see the entire glass and steel structure in front of the Louvre Museum. This one of the most popular display of glass in architecture.

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Next, we talk about glass facades with frames. In this picture, glass has been put inside a framing system. The strong frame lines are visible, of which a portion is openable, even though you do not see the actual frame. Glass fibers may also be used as reinforcement in corrugated items (see picture). These fines strands, which you can see inside, are all glass fibers.

These have strengthened this corrugated surface. If the base surface is of plastic, you get a special material called "Glass Fiber Reinforced Plastic" (GFRP). So, we can use glass in different ways for multiple purposes in buildings. We will discuss them one by one. Here is another picture of glass fiber being pushed into a wall for insulation. You can see some wooly material being pushed in.

As you see, the person is wearing thick gloves and a helmet, and even his eye must be protected with goggles (which is not visible in this picture due to the helmet). Even though the glass fiber is a soft wooly cotton-like item, the person has to protect himself because those fibers are sharp and thin. He should also wear a face mask because these thin strands of glass may otherwise get inhaled into the respiratory tract, causing massive internal injuries.

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We will now discuss the stages of manufacturing and the ingredients that make this totally transparent material. The three stages of manufacturing are- ‘melting’, ‘forming’, and then ‘finishing’. ‘Melting’ implies the melting of the ingredients in their prefixed proportions when mixed with water and heated in a furnace. A lot of bubbles will come out, and gradually, the product converts into a mass, very fluidic in nature.

After that is the stage of forming (or shaping). A viscous material will come out at a temperature of 800°C. There are multiple ways of “forming” the glass- by blowing, or flat drawing, or compression moulding, or spinning to get fibers; another method is by annealing (to get different strengths).

We will discuss these one-by-one. In blowing, you can get the desired shape. The glass has to be allowed to cool in that particular shape, which finally becomes the item of the specific (as desired) shape. What we are more interested in our subject is ‘flat drawing’. By the term, it is quite clear to understand that the final product will be a flat surface. Here, we get the glass in sheet form. One crucial point is to know the size limits of this sheet of glass; how large or small can they be?

As you know, it is brittle. Thus, we cannot go for huge sizes, where there will be limitations of making it and also address the issue of brittleness. Glass sheets can be flat drawn by rollers, and you get around 3 m × 4.5 m sheet of running length. You have to allow it to cool to get the flat-drawn sheet.

In ‘compression moulding’, you put the molten glass into moulds and allow it to cool down- the glass gets the desired shape according to the mould. ‘Spinning’ is again another way to obtain glass fibers, and annealing helps to obtain glass of different strengths as desired.

Annealing is a process of slow cooling of hot glass after they have been formed glass. Due to slow cooling, we can get different strengths (particularly higher strength glass) of it. And after performing these operations, we can get the desired form of glass- mostly, it is flat drawn. For obtaining glass fibers, spinning is employed. If we want a set of strengthened glass, we consider annealing.

Once the glass is formed, we proceed to the finishing stage- which involves cleaning, polishing, and cutting. You have to clean the surface, polish it if required, and finally cut it to get sharp edges. If you see the cross-section of a glass piece, you will see it is light-greenish in color due to the presence of iron oxide in it. Thus, with the addition of iron oxide (at the manufacturing stage), this greenish tint comes naturally to it.

You may also add mineral oxides or metal oxides to get different colors. We will discuss those towards the end of this lecture.

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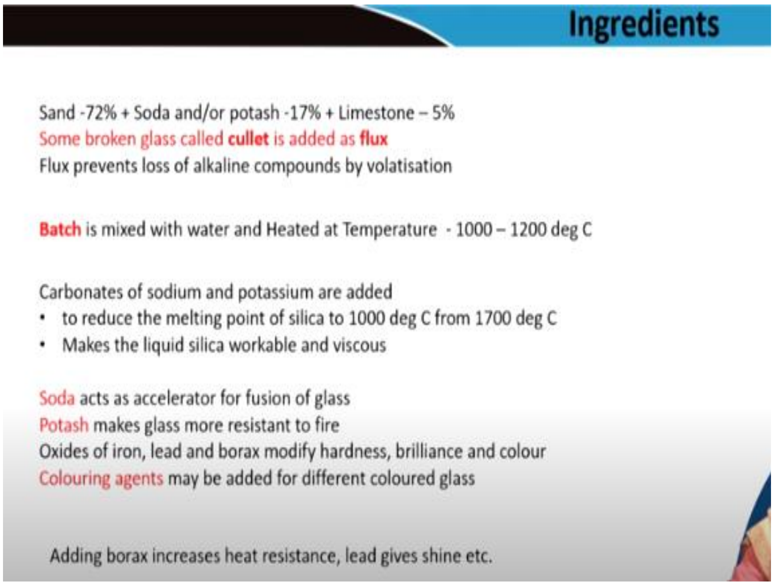

Let us see what the ingredients that constitute glass are. In clay bricks, we had seen that one of the main constituents is sand. It is again sand here, along with soda or potash and limestone. You add some broken glass in the furnace, which is called ‘cullet’, and it acts as a flux. It helps to reduce the temperature in the furnace. Flux prevents the loss of alkaline compounds by volatilization.

The sand, soda, potash, limestone, and cullet- all these are finely ground, and this entire item is mixed (called ‘batch’) with water and heated to a temperature of 1000-1200°C. Carbonates of sodium and potassium are added to it, which reduces the melting point of silica from 1700°C to 1000°C.

Thus, adding carbonates of sodium and potassium reduces the furnace temperature (results in energy savings). It makes the liquid silica more workable and viscous. This workability and its viscosity should be maintained so that the glass can be properly drawn. The functions of soda, potash, oxides of iron, coloring agents are mentioned here. Soda is the accelerator for the fusion of glass.

Potash makes it resistant to fire. Even borax makes it resistant to heat. We know about borosilicate glass. So, borax and silica make it fire-resistant. Adding oxide of iron, oxide of lead changes the hardness, brilliance, and color. The term ‘brilliance’ in the glass industry relates to the manufacturing of artificial lighting, which is not directly in our domain. Thus, we can add lead to make it more brilliant.

Regarding coloring agents, the different metal oxides impart a varying set of colors to the glass. We will elaborate on the colors obtained from specific metal oxides later. Borax increases heat resistance; lead gives shine, iron oxide imparts strength. This is how glass is made with specific ingredients.

You can change the proportion of ingredients to some extent to obtain varying properties or characteristics, resulting in different kinds of glass.

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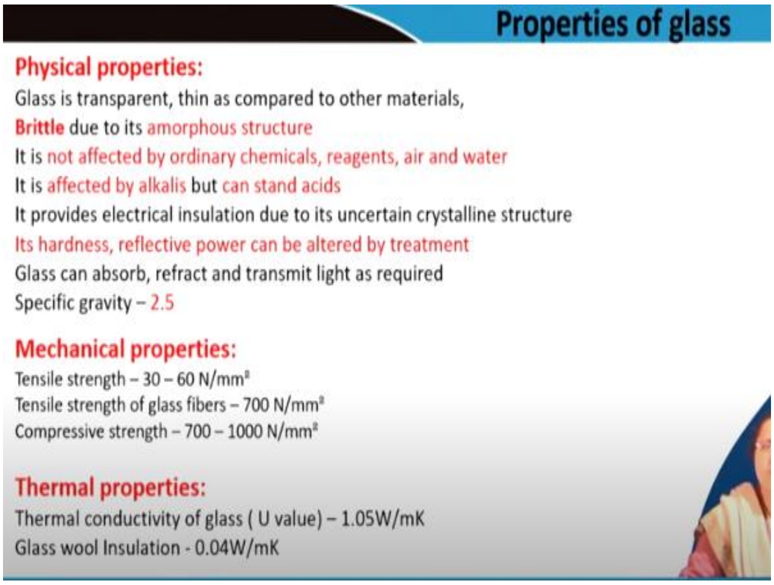

So, let us now focus on the properties of glass. As already mentioned, glass is transparent and much thinner compared to other building materials. Due to being thin, the knowledge of its' thermal properties becomes crucial. Glass is brittle due to its amorphous structure, as already discussed. It is not affected by ordinary chemicals or reagents, air, and water. It is impervious and does not allow air and water to pass through it.

Glass is not affected by acids at all but may be affected by alkalis to some extent. So, this is an ideal, non-reactive item that can be used in chemical, biological, and medical laboratories (finds popular application in pathological laboratories). It does not absorb any kind of microbes and provides a completely clear, stain-free surface.

Its hardness, reflective power- all can be altered by treatment. The reflective power of glass implies the amount to which the light gets reflected after bouncing off the glass surface. It will transmit some portion of light. We will discuss those when we discuss the different types of glass. Glass can absorb, refract, transmit light and also reflect light as required. Its' specific gravity is 2.5. As far as the mechanical property is concerned, the tensile strength varies between 30 to 60 N/mm².

For glass fiber, the tensile strength is much higher, around 700 N/mm². Its' compressive strength varies between 700 to 1000 N/mm². So, glass possesses quite satisfactory mechanical properties suitable for use. Coming to the thermal properties, the U-value of glass is 1.05 W/mK and varies from 0.8 to even 1.25.

Here, I am mentioning the average value. Notably, glass wool has a much lower U-value (0.04 W/mK). Therefore, glass wool is much effective in providing insulation.

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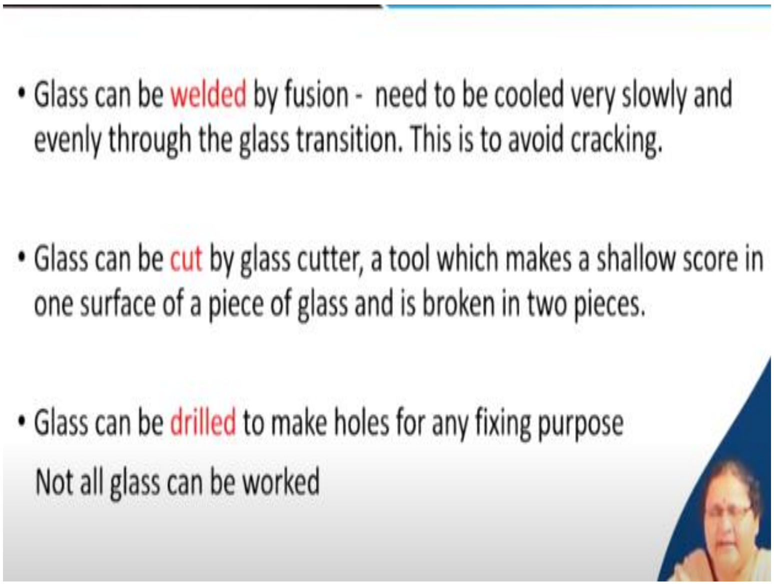

Now, we come to the workability of glass. Can we work on glass with similar ease as that of wood? We can cut glass into the desired size. Regarding drilling holes into glass- it is possible for only a few particular types of glass. Welding glass like other metals is possible, but we must be cautious since grass is brittle.

As far as the temperature transition during welding is concerned, glass needs to be cooled very slowly because during welding operations, a temperature gain (heat) occurs in the local area at the joint (between the two pieces which are being joined) where it is being welded. So, sudden cooling of the area is not favourable; otherwise, it will lead to cracks.

The same precautions must be maintained for drilling. When drilling glass, you must remember that you cannot be careless and treat it like wood or brick since glass is a fragile or brittle item. The experienced workman already knows these facts, but as an architect, you should also be aware of the possibilities and corresponding precautions needed for these three main operations during usage- cutting, drilling and welding glass during building construction.

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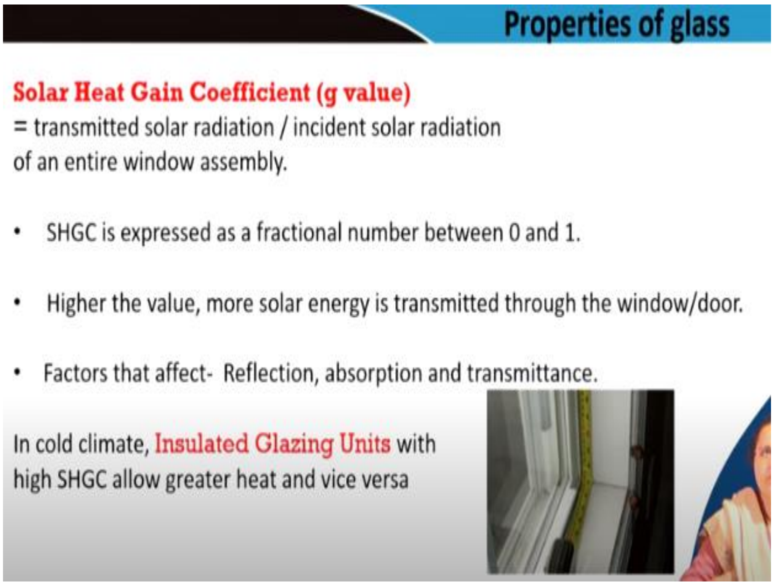

Let us move to another property, the "Solar Heat Gain Coefficient" or SHGC of glass, also called the g-value. It is the ratio between transmitted solar radiation through the glass surface and the incident solar radiation on it.

$$\text{SHGC} = \frac{\text{Transmitted solar radiation}}{\text{Incident solar radiation}}$$

Thus, if there is a window with one glass pane, the transmitted solar energy inside the building, divided by the total energy incident on is the g-value of the glass.

Since it is a ratio, it must lie between 0 to 1. If the glass transmits the entire energy, then SHGC= 1, and if it is filters some radiation from penetrating inside the building, then SHGC < 1, and you have better control of the solar energy. Higher the value of SHGC, more is the solar energy transmitted into the building through the window.

Thus, reflection, absorption, transmission- these three factors affect this solar heat gain coefficient. In cold countries, glass with a higher g-value is favourable. For hot regions, we want the value to be lower. Here, most of the incident energy should be reflected out. In other words, the transmitted solar energy should be lower than the incident solar energy. This is also is a specific quality of glass and is essential when choosing glazing systems having different values of solar heat gain coefficient. We will discuss this part later on.

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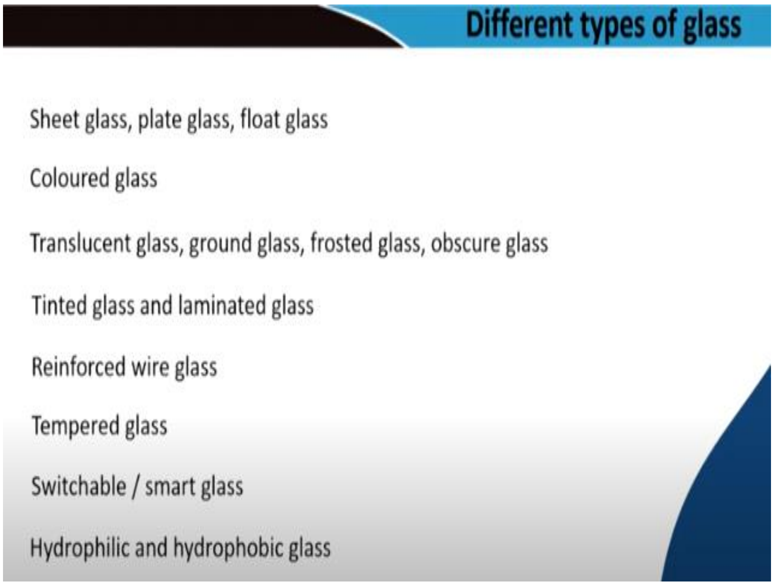

Now, let us look into the different types of glass (which we will elaborate mostly in the next lecture). As mentioned earlier, we have sheet glass, plate glass, float glass, colored glass. Another group of glasses consists of translucent glass, ground glass, frosted glass, obscure glass, etc., all of which are mostly similar in function. The other types include tinted glass, laminated glass, reinforced wire glass, tempered glass, and switchable smart glass.

Lastly, there are two special types- hydrophilic and hydrophobic glass. So, you can understand that it is not just one type of glass that is used in a particular building. For different types of buildings with varying purposes, we can use the corresponding type of glass, which we will elaborate on in our next lecture. Thank you.