Building Materials And Composites
Prof. Sumana Gupta
Department of Architecture and Regional Planning
Indian Institute of Technology - Kharagpur

Lecture – 13
Glass (Continued)

Hello, everybody. Today we will study lecture 3 of module 3 on “Glass and Ceramics”. In the earlier lectures of this module, we discussed the different types of glass, methods to reduce fragility, and increase the safety of the glass- by various ways, such as lamination, increasing the solar heat gain within the system, etc. We also focused on strengthening the glass by tempering (or heat treatment).

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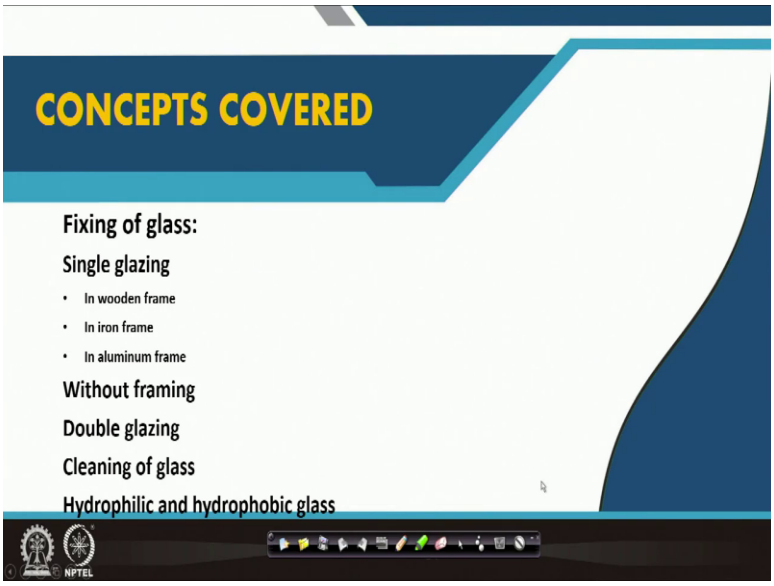

In this lecture, we will talk about the fixing of glass in a system. As you can understand, glass is a thin and fragile material. We have to be very careful when fixing it. In the building industry, the primary applications are in the domestic windows and doors. Also, there are some specific areas where particular types of glasses must be used. In India, single glazing windows are most popular, which is basically one layer of glass protecting from the environment and allowing visibility. Also, it must be sufficiently safe.

The glass should not fall off from the system where it is attached. In windows and doors, we use wooden, iron, or aluminium frames with glass panes in them. Also, there should be no (or minimal) any gap between the outside space and the interior to protect from the weather.

The glass should be placed in such a way that dust, dirt, wind, or rain cannot enter the interior. At the same time, this helps in preventing the interior thermal environment get exposed (or intermixed) to the outdoor weather conditions. Thus, neither the external elements should be allowed to enter inside nor vice-versa. Therefore, the glass should be able to provide thermal protection.

In offices, institutional buildings, commercial plazas, etc., in cities across the world, large entry spaces with complete glass facades (without any framing) are trendy nowadays. It is a kind of application where the glass stands without a frame and still provides the same level of protection as a regular framed glass panel or a masonry wall.

This kind of frameless facade may be seen in shopping malls, hotels, etc. So, we will also see how the framing is done. Quite obviously, such glass must be of the strengthened/ toughened type (tempered glass). Also, we will discuss the double glazing units- which have unique thermal advantages. This will be followed by the techniques to clean glass. This lecture will be a long one.

Cleaning of glass is necessary because the real charm of glass lies in its see-through nature. If full of dust and dirt, it will lose its appeal. But at larger heights, it becomes a challenge to clean glass surfaces due to limited accessibility. Cleaning may be somewhat possible from the inside, but not easier from the outside. We will discuss those issues towards the end of this lecture. We will also discuss hydrophilic and hydrophobic glass- types of nano-coated glass that can “self-clean” itself.

Self-cleaning glass is somewhat modern technology and, therefore, has limited popularity. Although it works only under certain conditions, it is beneficial in the maintenance of vast glass surfaces.

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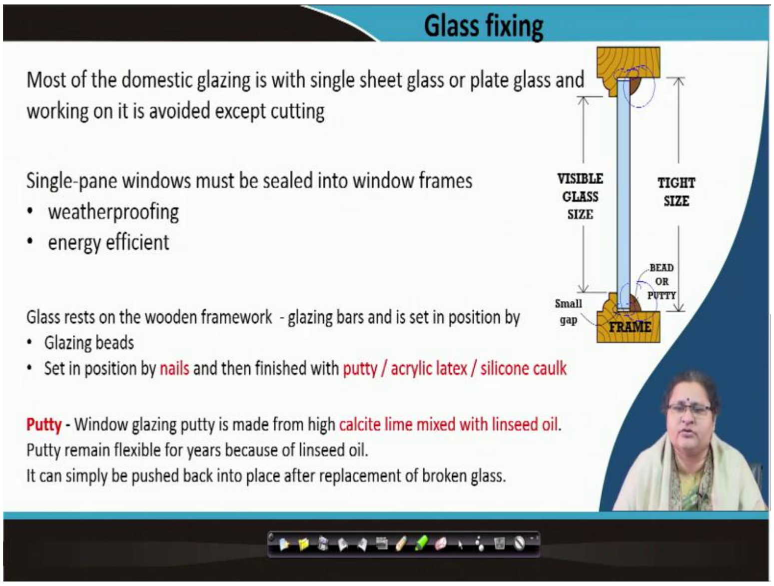

In this slide, you see the diagram of glass fixed on a wooden frame. It may be simply a plate glass, sheet glass, or float glass, and is thus, very fragile. This attachment is done without any drilling or welding. In the wooden frame system (you can see the upper and lower frame in section view), the glass piece is being inserted and fixed in place by putty (see diagram in video).

This putty may be replaced by a glazing bead too. There must be a small gap to allow the expansion of wood or glass. The sealing must ensure weatherproofing to increase energy-efficiency (i.e., disallow movement of heat energy). This keeps the internal condition intact. As you can see, the putty may be replaced by a bead (wood piece) attached to the wooden frame by nails.

The glass pane is initially held in the position either by glazing beads or by nails. In the second case, the edge joints must be later finished (filled) with putty, acrylic latex, or silicone caulk. The most used filler is 'putty' - which is calcite lime mixed with linseed oil.

The linseed oil gradually evaporates, and the putty (a sticky substance) remains in position for a few years. Since nails were already used to hold the glass in position, the glass will stay in place even if a part of the putty lining comes off. If necessary, the old putty may be taken out, and the joints re-sealed by a fresh putty. Except for any sudden impact force, it is unlikely that the glass would fall off or break. So, visibility is achieved through the window, and the glass is now held in position.

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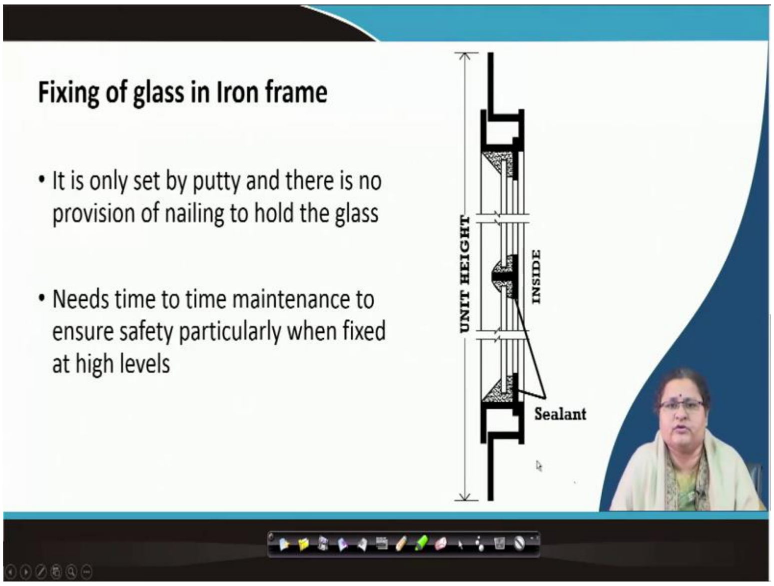

In this next slide, we will talk about the fixing of glass in an iron frame. The sectional details are given here. This is called a Z-section, which forms the frame. You can also see the sealants into which the glass is embedded. Again, here is a T-section.

The putty holds the glass in position. Also, you will find no nails because it is not possible to fix nails within an iron section. Unlike earlier cases, here, it is only the putty that holds the glass in position. Periodic maintenance (replacement) of the window putty is necessary, particularly if it is at a high level so that the glass does not accidentally fall off.

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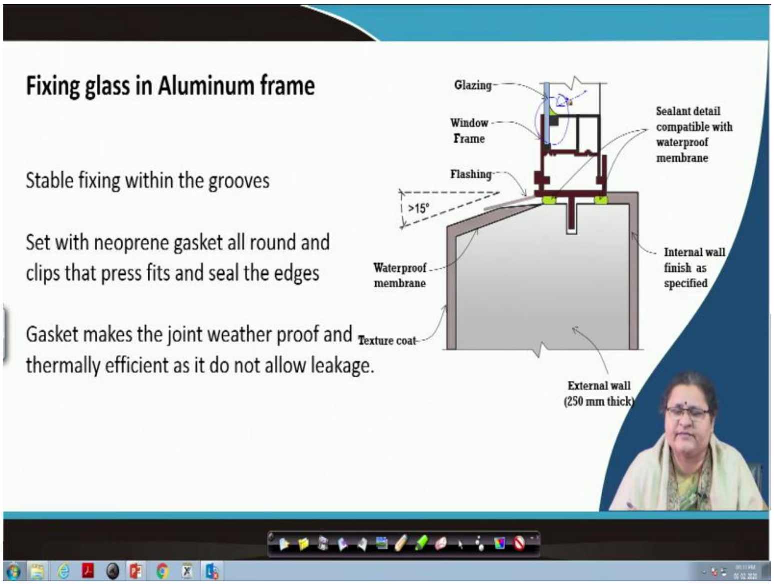

Let us see what happens in aluminium frames. Nowadays, we refrain from using wood frames for environmental reasons. Iron and aluminum frame sections are becoming popular. In the picture (see diagram in video), the glass (blue color) is set within the frame, and a sealant is applied, which not only keeps the glass in position but also makes the joint waterproof.

Gaskets or press-fit clips may be used. Aluminium press-fit clips are soft- that go inside the space to hold the glass in position. Aluminuum frame has a better locking capacity with the glass than wood frames. You may use sealants, but gaskets or aluminium press-fit clips are generally used. Aluminium is the best choice compared to iron and wood frames.

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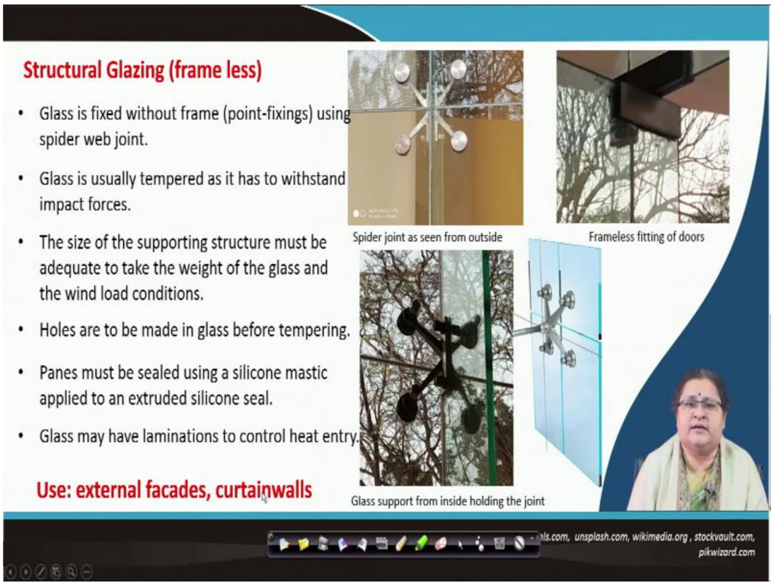

We will now discuss the structural glazing or the frameless glazing system. In the pictures here, you can see the ‘spider joints’. These help to fix glass at intermediate points, without the need for a frame. The views of the assembly (after installation) from the front, back, and sides are given (see images in slide).

On the image at the upper right (see image in slide), a door is seen installed with this frameless joint. You can see the wooden supports, with pivot-type of fixing. The hinge is pushed into the glass panel, which helps it rotate. The glass used here is tempered glass, since it must be strong enough to withstand any impact force. Moreover, there are no frames to support the structure, so a high-strength glass becomes necessary.

The entire assembly rests on a glass member; that is, the joint is resting on a glass support. Thus, the support should be strong enough to sustain the load of the entire façade. Sometimes, the support may be a steel rod. All these images are from the Technology Students Gymkhana at IIT Kharagpur.

Here are some pictures (see image in video) of a two-floor atrium with a glass façade. The glass support holds the glass in position. Steel rod supports are mostly found in shopping malls whose facades are much taller in height (two to three floors height).

Any hole that needs to be made in the tempered glass must be made before the tempering stage, as already mentioned. After tempering, any kind of cutting, drilling, welding, etc., is not possible. So, the locations of the spider joints- all have to be designed beforehand and ordered accordingly. On the site, you just have to install them.

Panes must be sealed using silicone mastic applied to an extruded silicone seal. In this picture (see image in video), between the gaps of the four glass panes, you can see the silicone mastic (not the putty). It has a longer lifespan and almost colorless. Hence, the joints that are formed are very thin and seamlessly merges with the glass, preserving an all-glass look, even though silicone mastic has been used for joining them. It seals the interior from the external weather conditions and transfer of heat.

Furthermore, glass surfaces may have laminations. For tall buildings, it is essential to calculate the solar heat gain within the buildings. So, it is necessary to reflect a part of the solar radiation reaching it. The laminations on top of the glass help in controlling heat entry. Laminated glass is popularly used in external facades and curtain walls of buildings, showroom windows, shopping mall facades, etc. Glass walls are almost as strong as a brick wall, with the added benefit of transparency.

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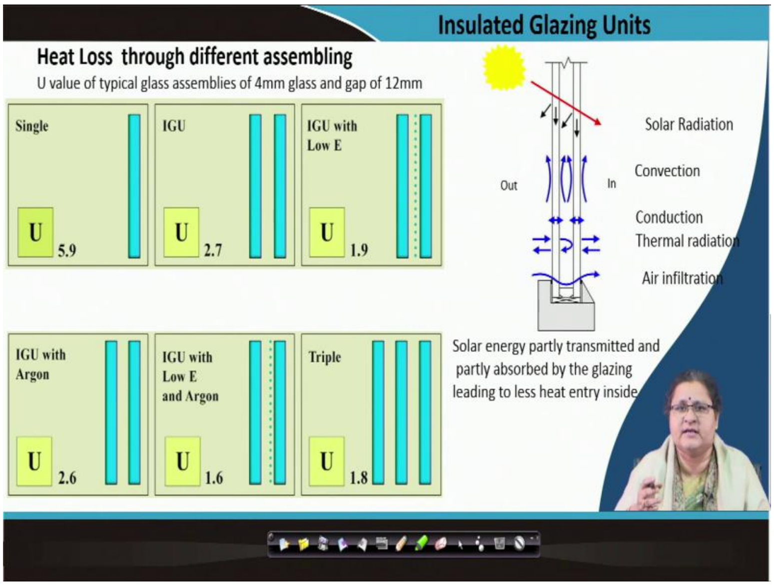

Now, let us move to the next slide. Till now, our discussion had been limited to single glazing, and its U-value was 5.9 (see diagram in slide). Now, when two glass panes (each 4 mm thick) are used, with an air gap (around 12 mm distance) in between, the U-value of the assembly reduces to more than half (becomes 2.7) than in the single glazing. For this third case with a dotted line (see diagram in slide), the U-value has further reduced to 1.9. Both of these are Double glazing units (DGUs).

Here, the dotted line represents a low-E lamina. Thus, if you can add a lamina when assembling the product, it will further reduce the U-value. In this situation, the solar radiation (red-colored line in the given diagram in slide) first strikes the outer glass pane- when a part of it is absorbed by the glass, and the rest is reflected out. Whatever part is entering the window undergoes convection when it comes in contact with the air gap sandwiched between the two glass panes.

The heat is conducted from one surface of the glass to the other surface, and some part is radiated inside. So, only is a fraction of the total solar radiation is entering the interior. If there had been only one glass pane, a part of the incoming radiation (red line in the diagram from video) would have been absorbed by the glass, a part reflected outside, and the rest- reaching the interior.

Some of the incoming radiation will pass through the glass pane by the process of conduction. It will get further reduced on touching the air gap between the panes. Hence, this kind of assembly helps in minimizing the radiation that finally reaches inside. A low-E coating on the glass decreases the radiation further. Additionally, if the air inside the DGU is somehow extracted and replaced by an argon infill, the performance of the unit will reach its peak.

Thus, with a double glazing unit using argon infill, the U-value is 2.6, whereas, with air infill, the value was 2.7. If you use an additional low-E coating in the DGU with argon infill, it will further come down to 1.6. In the case of a triple glazing unit with air as infill, the performance will be similar to the DGU with low-E coating and argon infill or the double glazing unit with just low-E coating (without argon infill).

In this triple-layered assembly, we are basically increasing the weight,.and thereby, the material cost. By inserting the lamina, the U-value gets reduced. These insulated glazing units are generally used where the glass surfaces are large, as in high-rise building facades, where we want to control the heat entry.

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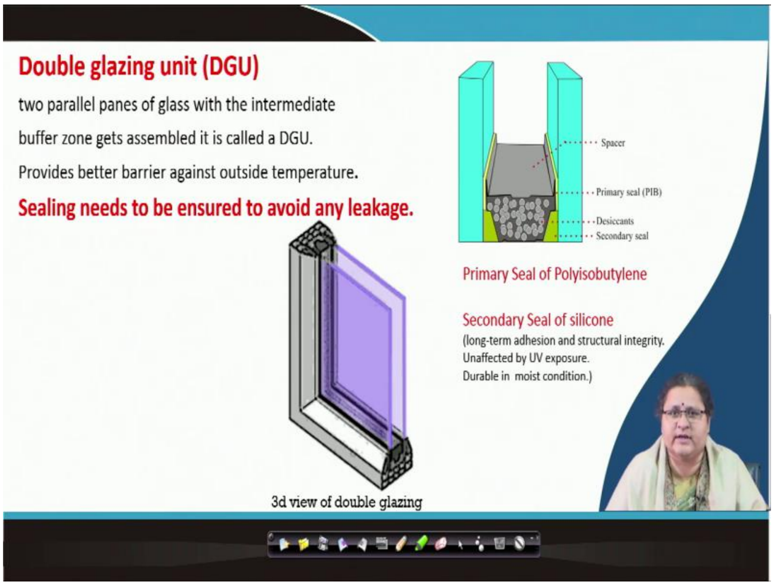

Let us see what happens in double glazing units. Here, the insulated glazing unit (IGU) has two layers, i.e., two parallel glass panes, with an intermediate buffer zone- which may be filled with simply air or argon infill. The quality of sealing of the assembly is essential here.

If you look into a larger detail of this area, you can see the two glass panes. In the frame, there is a primary sealing, a secondary sealing, and desiccators. The sealings eliminate chances of any leakage that may lead to malfunction of the overall system. This is crucial since any small gap remaining would render all calculations wrong, and the advantage of the double glazing units would be lost.

The window section shown (see image in video) that is eventually developed- is available in the market. The structural integrity of the system remains maintained, only if the sealing keeps a long term adhesion to the system. It should remain unaffected by the ultraviolet rays of the sun and should be durable even in a moist environment.

The part (outer) of the DGU will always face the external weather conditions, and the other part (inner) faces the controlled (interior) condition. Thus, the assembly must be able to adjust to the temperature differences throughout its' lifetime. As discussed, the integrity of the sealing is mainly responsible for the overall performance of the product.

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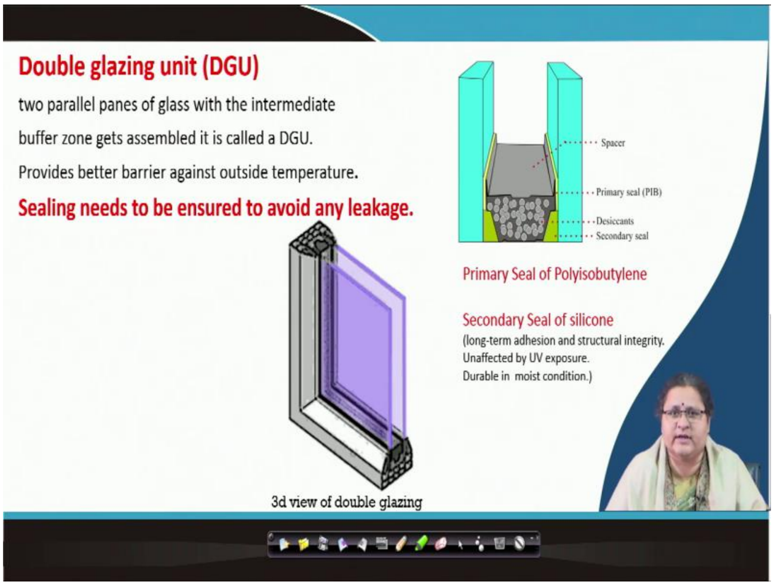

Another application of glass is in solar panels. We will not cover the details. Basically, on top of every solar assembly (solar photovoltaic cell), there is a glass layer protecting the entire system. This diagram (see video) has been redrawn from a separate image, and you can see the glass, the aluminium frame, and the sealant. Below them is the photovoltaic assembly (the device that stores the electricity)

The glass that covers the photovoltaic panels should be highly transmissive, such that any portion of received sunlight is not reflected. The glass should be able to attract or entrap the solar radiation. Since the panels have to be oriented in such a way that maximum sunlight is captured, it must be strong enough to withstand any accidental impact force. Also, as it is difficult to replace the glass frequently, a transparent or anti-reflective coating is added to it to increase efficiency.

This is another area for the application of glass as a building material. Glasses in solar panels may be cleaned with liquid water or vapor (steam), such that it remains free of dust and dirt, to capture the maximum energy from the sun.

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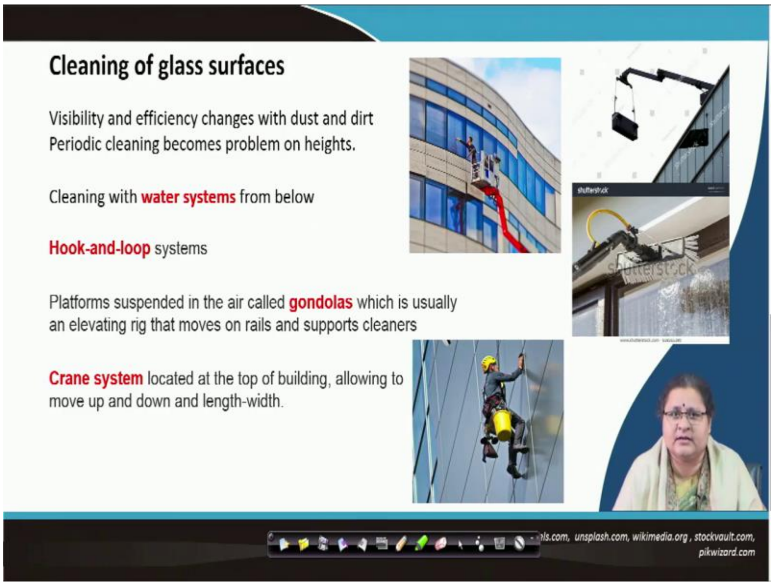

Let us talk about the cleaning of glass surfaces. As I have already said, a glass surface can be appreciated only when it allows visibility through it. A dirty glass surface reduces visibility, efficiency, and therefore its' charm is lost. So, periodic cleaning of glass is essential. At heights, cleaning poses a formidable challenge. In general, a water pressure washing system is the easiest. From the ground level, it may be possible to clean glass surfaces by throwing water up to a maximum of two or three floors in height.

But this system is not effective enough at higher levels. Sometimes, a hook-and-loop system is used, where a person is hooked up and moves along a cable parallel to the glass surfaces, gradually cleaning them (see image in slide). However, this is quite labor-intensive and takes a lot of time for completion. Another technique utilizes suspended "gondolas"- an elevated rig that moves on rails parallel to the building (see image in slide). Cleaning workers stand on the gondolas and clean the glass surfaces.

In this image (see image in video), the crane (stationed on the ground) is lifting the person on a platform who will perform the cleaning job. This is a time-consuming but effective way of cleaning. Another way is to position the crane on the roof of the building and move the arm along the building façade- in the vertical direction and sideways (as necessary), carrying the worker who performs the cleaning operation.

Hence, having large glass facades also demands the availability of proper maintenance facilities; otherwise, the façade would look poor and also may be functionally inefficient.

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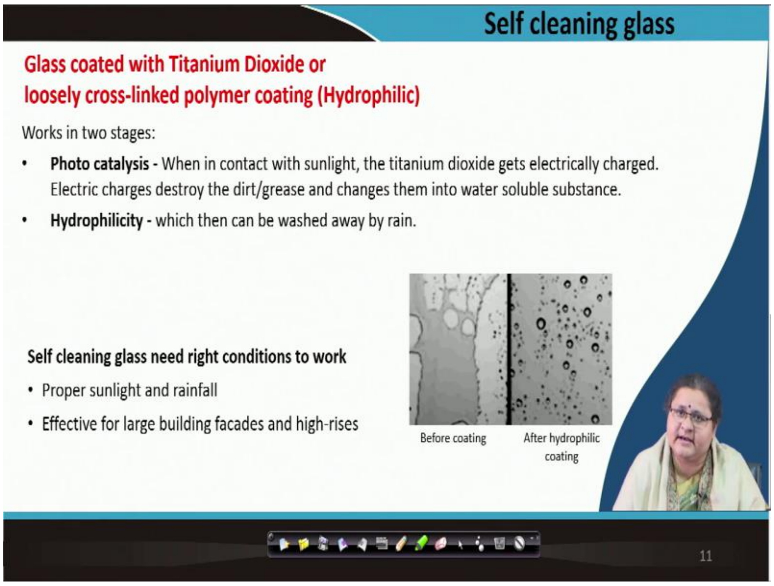

We will now explore the self-cleaning glass, a novel application of nano-technology. Such glasses are mostly seen in the automobile industry but are also being used in the building industry. Here, the glass is coated with titanium dioxide, or a loosely crosslinked polymer, which attracts water. The process has two stages- photocatalysis, where the titanium dioxide gets electrically charged in the presence of sunlight. The electrical charges destroy the dirt or grease adhering to the surface and change them to water-soluble substances.

The second stage is the attraction of water by the surface- the water-soluble substances get washed away by the water . Thus, in this method, initially, the dirt gets loosened (converted to water-soluble substances) in the presence of sunlight. Later, the loosened dirt is flushed out by rainwater.

Self-cleaning glass requires a proper amount of sunlight (in the presence of titanium dioxide or cross-linked polymer coating) to break down the dust and grease to water-soluble substances. Also, the rainwater is necessary for efficient final cleanup. So, if the amount of rainfall received is higher, the cleaning would be better. Here, the presence of coating is also vital- without which the oil and grease would not get washed as easily.

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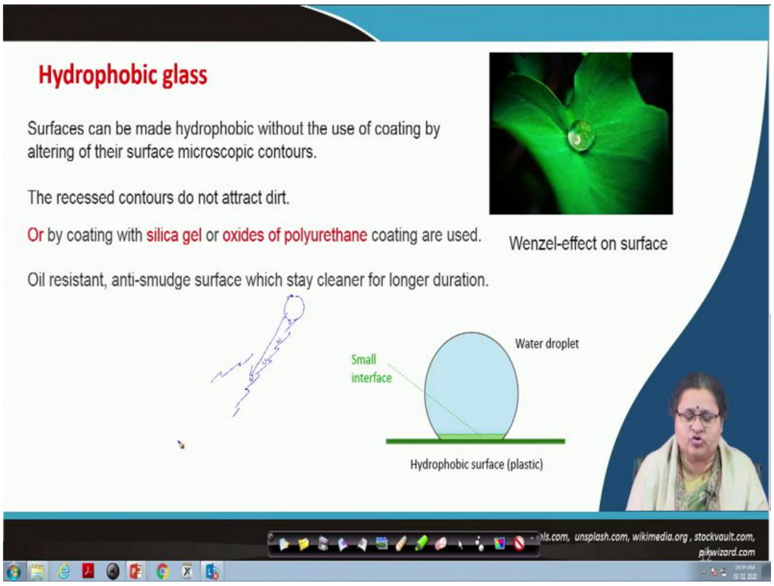

Another kind of system is that of hydrophobic glass. Think of a lotus leaf. It always grows on water, but any water on top of the leaf does not spread out throughout the leaf surface- it forms clusters (or droplets), always trying to get off from the surface. This surface may have serrations, and the dust or dirt are gradually carried (washed) down by the water droplets

The recessed contours do not attract dust, i.e., the dirt does not get into the serrations and remains on the top. Alternatively, the surface may be coated by silica gel or oxides of polyurethane to achieve a similar effect. A hydrophobic surface is oil-resistant, anti-smudge, and stays cleaner for a long time. The water droplets that trickle down now develop a much lower contact with this surface. Below this hydrophobic layer is the actual glass surface, which remains clean.

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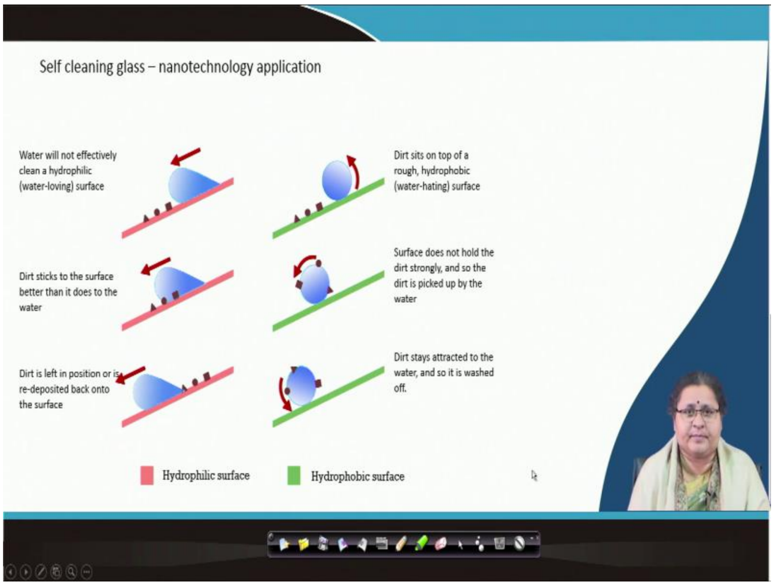

Here is a better picture adapted from the internet. There is a hydrophilic surface, where the dust and dirt are shown by brown-colored granules, and the water droplet is not cleaning them as it trickles down. On the contrary, on a hydrophobic surface, the water droplet actually carries the dust granules and moves down. The force required to carry the dust particles may be sufficient by regular rainfall. But the grease and oil will get 'digested' in the same place.

The term 'digested' implies to change or transform into the other form due to the action of sun rays. The dust and dirt roll down with the droplet. These are two nano-technological phenomena that occur here- a relatively new application in the building industry.

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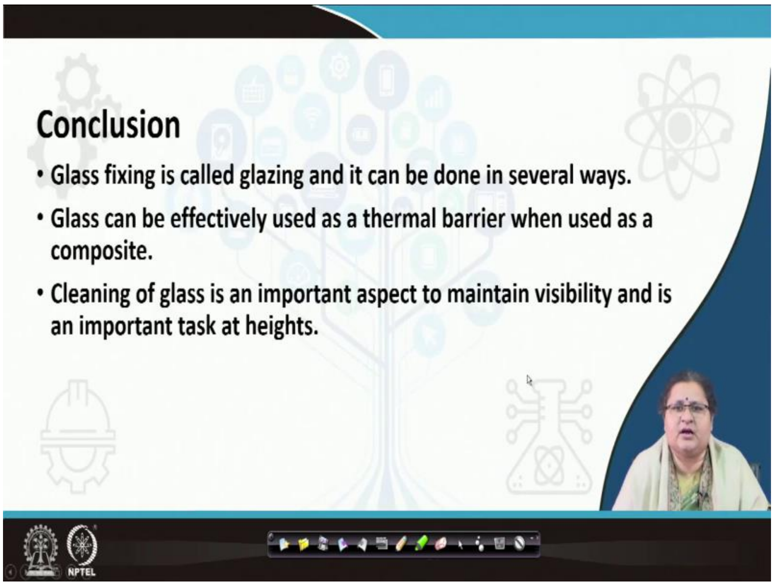

Thus, we conclude that glass can be fixed in various ways. The process of fixing is called ‘glazing’ (in this context), although the term has another meaning. Glass can be effectively used as a thermal barrier when used as a composite (subsequent layers of glass, air, glass). Cleaning glass is crucial to maintain visibility and is a challenging task at heights.

Various advanced technologies are being adopted in modern times for high-rise structures, such that the cleaning process becomes less cumbersome. However, they have some preconditions, which must be followed. We conclude this lecture here and will move on to the next (lecture 4), where we will try to explore another form of glass. Thank you.