Glass in buildings : Design and Application
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Lecture – 57
Glass Application on Facades

We are now going to explain little more on a design approach in various different aspect, not necessary engineering point of it, may be from different design point of view for facade system.

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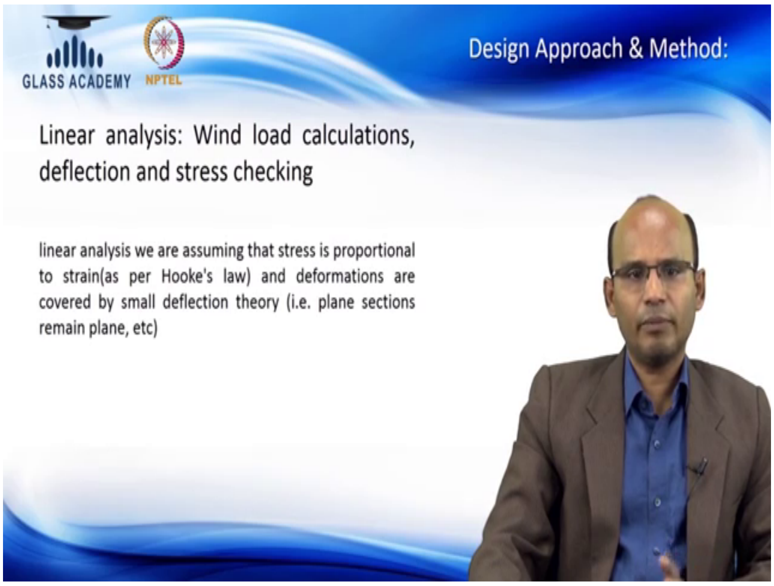

Linear analysis the design processes, we will be explaining the design process here. First, as engineer he will be the predominant load on the facade is wind load. So, we need to check the wind load and make sure the wind load is checked for all the major elements for stress versus deflection checks.

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The predominant force as we all know is wind force being small building big building or wind force is predominantly a natural criteria which is defining lots of components. So, wind is defining the performance of the building and it has impact on comfort, it has impact on a functional, due to the wind especially high rise building or tall building the it creates big differential pressure from internal space to external space and perception. Perception is something related to the occupants. The occupants feel is that it is moving too much then they do not feel comfortable. And, it is a safety aspects. So, the wind is giving multi-facet aspects to the engineering design.

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And, continuing with the wind; wind pressure on the facade mainly on the high rise buildings it has other secondary effects. It may sometime also define by the geometry if the building is circular or some curved we all know like, engineers understanding is the wind is flow smoothly on the circular building as compared to the square building. And, it has the peak pressure the engineer should know where is the peak pressure and it may not be non-linear the building when it goes taller and taller the pressures are not linear and if there the situation the wind tunnelling happens where the buildings are spaced closely.

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Wind is giving lot of challenges depending on the elements the wind pressure. Facade has different elements as mentioned before. It could be the wind is different the entrances which is impacting on the entrance facades, canopies or those sheltering the entrances as a different aspect. When it comes to the roof, the roof design is controlled by the wind. And, there are lot of shades, building corners. It may be a large openings on the buildings like access doors or maybe places where the building has the corner openings the this wind pressures are critical.

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Wind pressure is influenced by various define a different elements as mentioned previously. It could be on the roofing elements or there is large canopy which is on the entrances, it could have a big uplift force of this canopy which will define the design. If it is curved and smooth the wind pressure is much predictable, if it has a sharp corner with a lot of shades and sun shades, it will have an impact on the high peak pressures.

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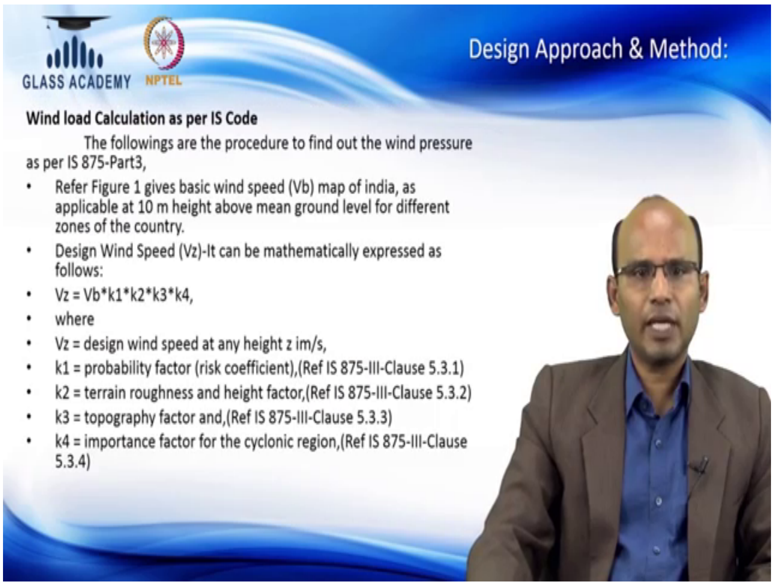

Wind load calculation it varies according to the local standard as per IS code here 875-Part 3 or the NBC 2016. The design principle is given here that is a basic wind speed and it has all this criteria factors k 1, k 2, k 3, k 3 and k 4 roughness terrain factors. If the engineer put all this numbers you will get the actual design wind pressure and the procedure is given in for example, IS 875-Part 3.

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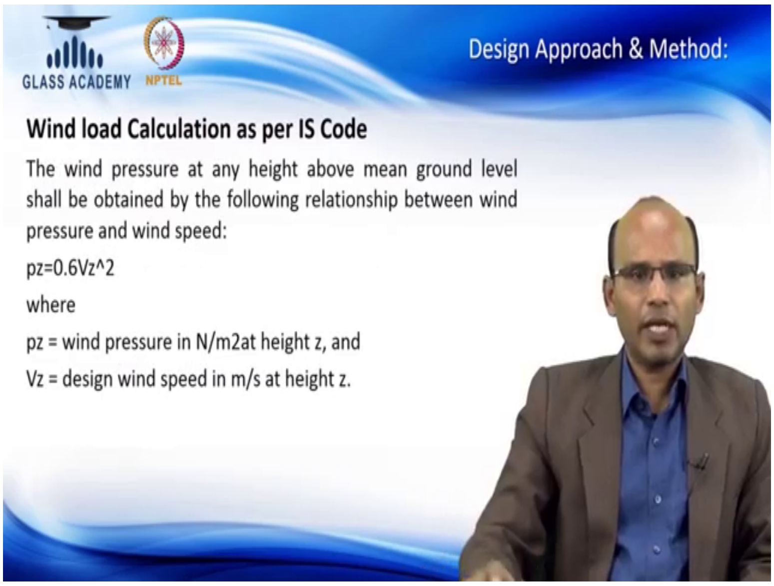
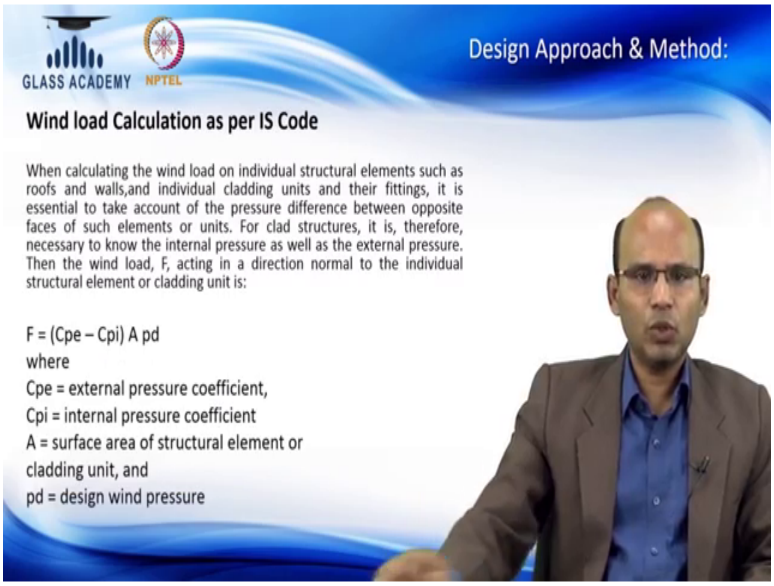


Wind load calculation as per code is primarily defined by the wind speed as define various cities as the different basic wind speed is given in IS code and wind pressure. So, the pressure is varying according to the height or the building. (Refer Slide Time: 04:31)



As per wind code, the engineer need to check the external pressure versus internal pressure and it should be multiplied by the exposed area of the building and design wind pressure. So, if you put all these factors we will get the net design wind pressure.

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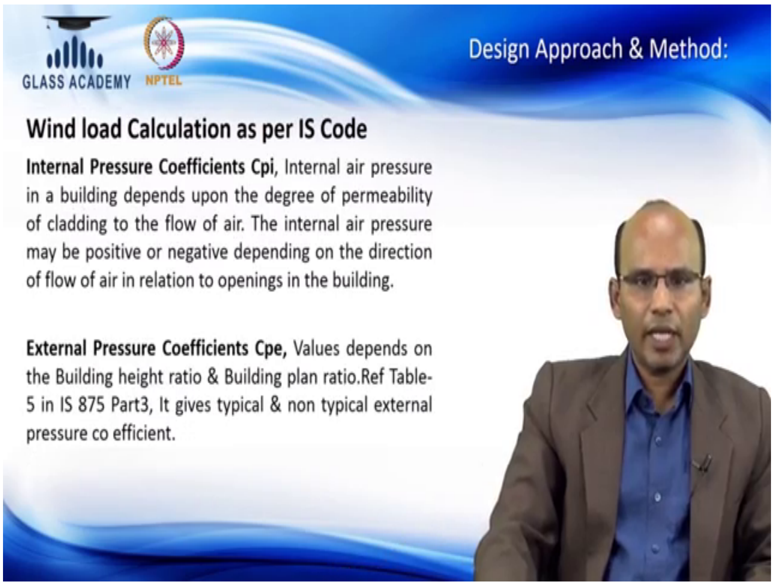

Wind load calculation is primarily two factors to be considered internal pressure and external pressure. Internal pressure is generally is taken as 0.2 to 0.3 plus minus and external pressure is calculated based on the wind pressure, building aspect ratio or terrain factors as various different factors. And, the net pressure is given the difference of these two external and internal pressure.

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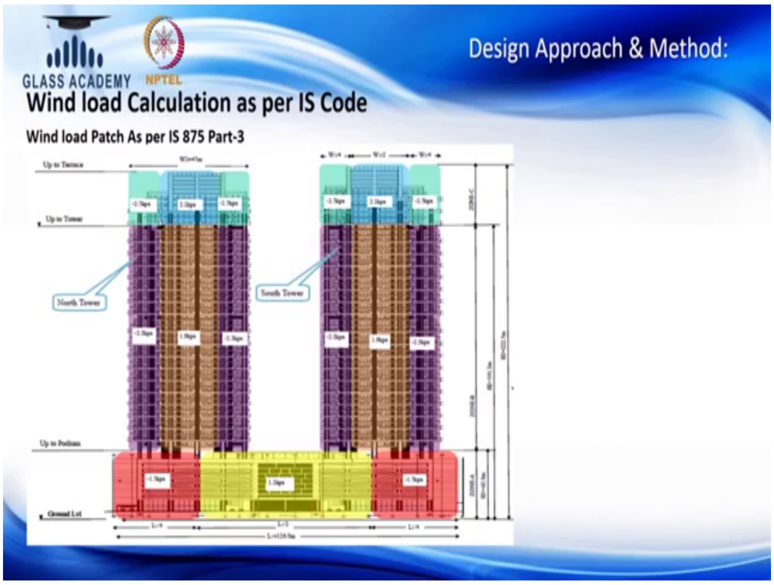

In real situation the wind pressure on the high rise building may not be consistent or uniform. As you can see the picture is taken from a real project of proximately about 50 storey building here. These two towers is given and you can see the wind pressure or acid goes higher, as well as the corners.

The corner wind pressure is much higher and the central portion is given in orange colour is of a different pressure and the roofs all the corners because, of this building has a lot of sharp corners the pressures are much higher on the corners. It sometimes not linear you can also see the wind patches here is even higher at the lowest podium level. This is showing a wind calculation stand as a typical high range building as per IS 875 Part-3.

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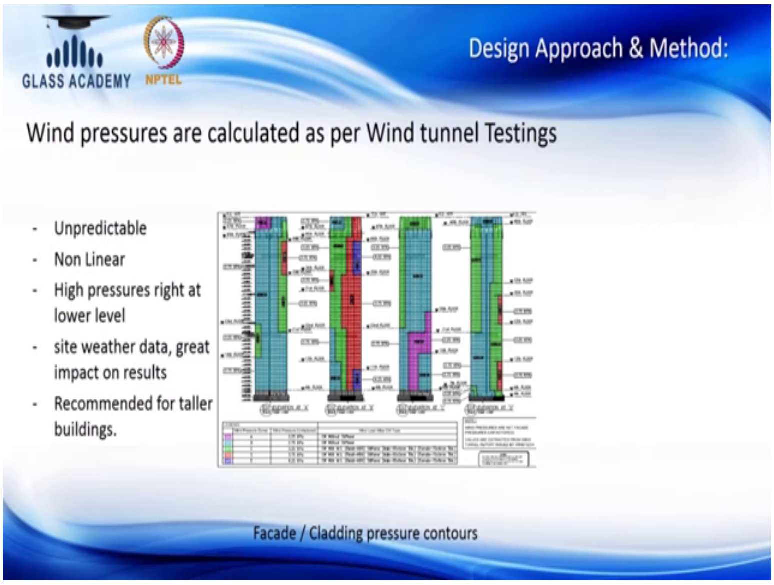
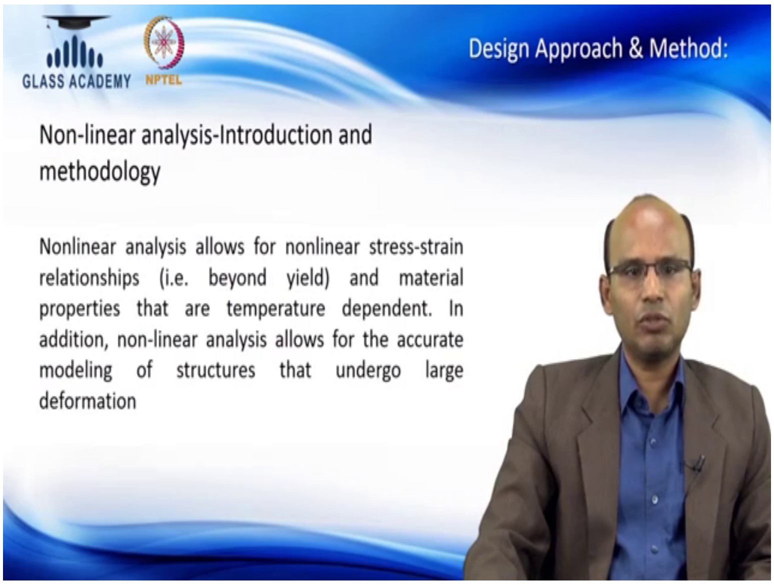


This picture is showing wind pressure is done from the wind tunnel testing. Wind tunnel testing is as engineer maybe familiarize different from the codal based analysis. The building model physical model is been checked in wind tunnel and the pressure is derived from the actual physical model study. And, as you can see the pressure is not linear it basic generally the red patches is the high wind pressure and the red patches is across the building spread here.

In this building the red patches is even visible at the lowest level here which primarily saying engineer may not assume everything is linear. So, it could be non-linear, the high pressure even very high at the bottom most here and this building is four towers on the particular size space it spaced very closely, the pressures are very high at the corner. So, it is a real case conditions is taken from the actual project, the wind pressure may not be linear it may be varying across. So, this has a challenge for engineers to design the system with suits for all different criteria at the same time is optimized to design. (Refer Slide Time: 07:29)



The engineer should be familiar little on non-linear analysis for facade being a glass panel or framing elements because, the pressure is varying and the framing elements or framing supporting framing it could also be splendour elements. Hence, non-linear analysis on facade engineering is part of the all the design process.

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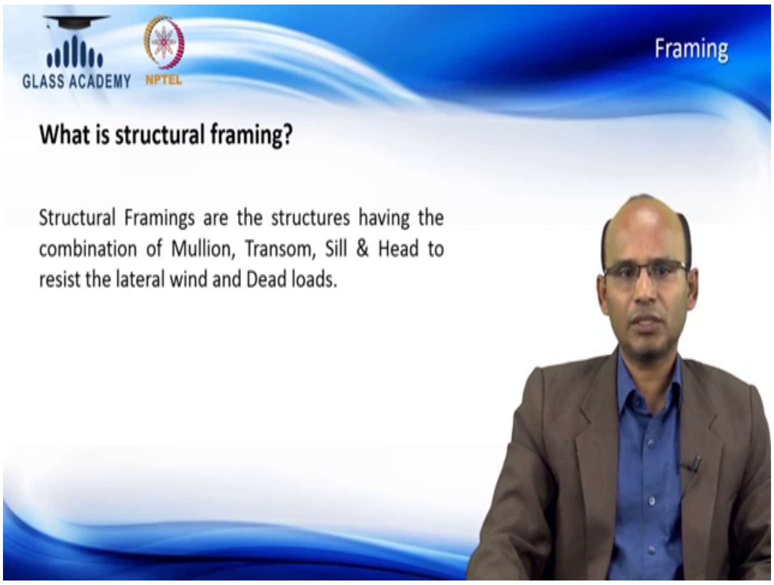

What is structural framing? The structural framing, essentially supporting the cladding panels being a glass of cladding; the terminology used to mullion is considered as main verticals or runners, its spanning on the longest ride. Transom is called as horizontal framing elements which primarily spanning on the shorter span. Sill and head section is given for wherever the joint is happening here and all these elements put together and an act as a facade system and it should resist lateral wind load and dead load as per.

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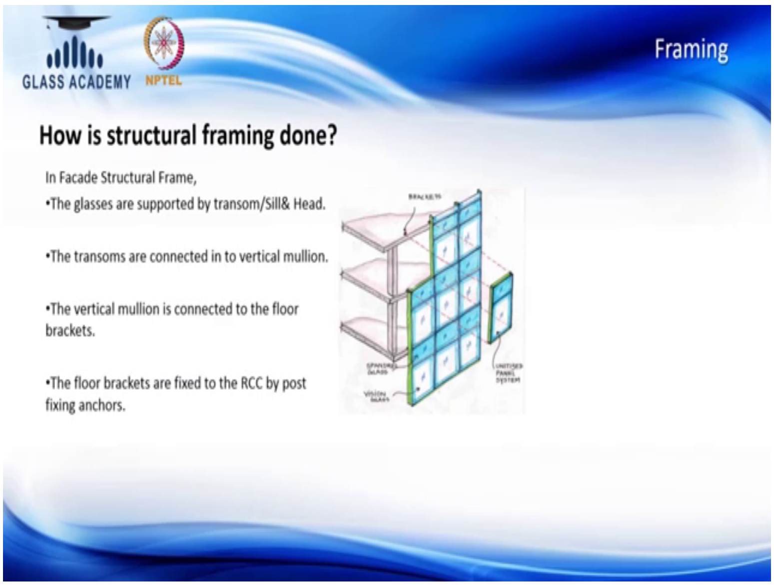
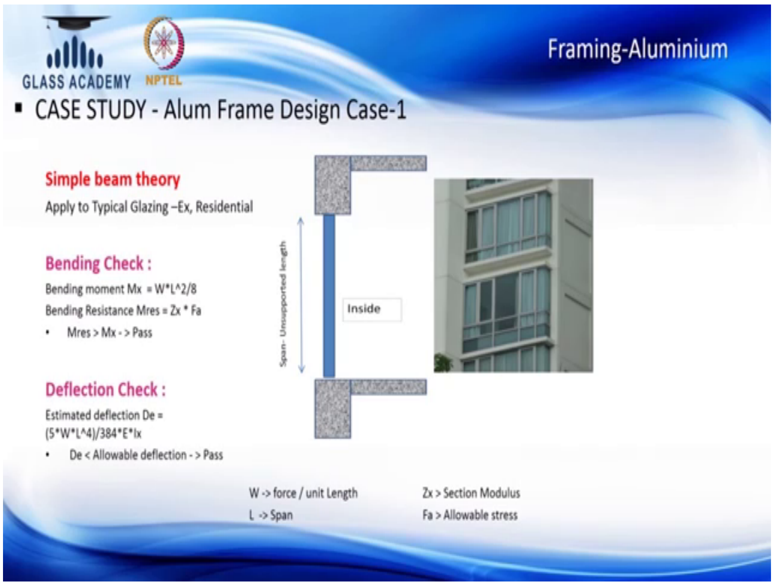
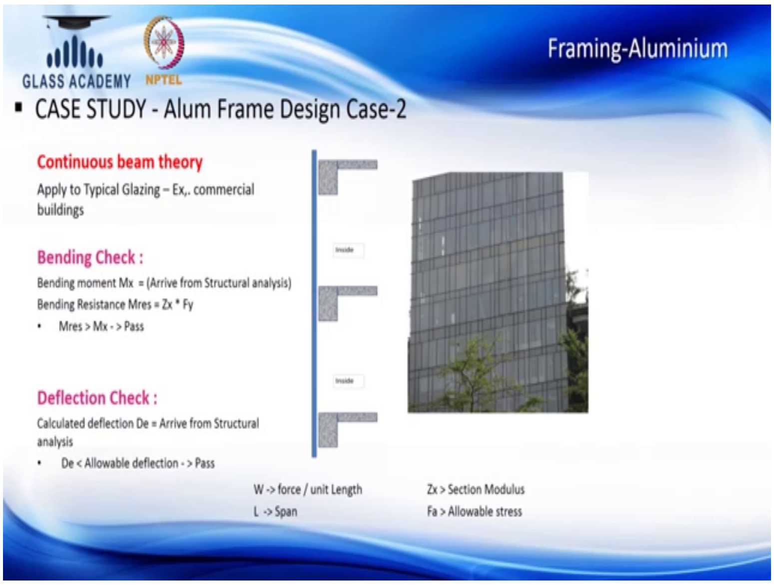


The structural framing is what you can see the framing around the glass panel or cladding panels of framing and in this system it is prefabricated system. So, that the framing what you can see the green colour is spanning from floor to floor. This is the height of the member which need to be a structural engineer. (Refer Slide Time: 08:52)



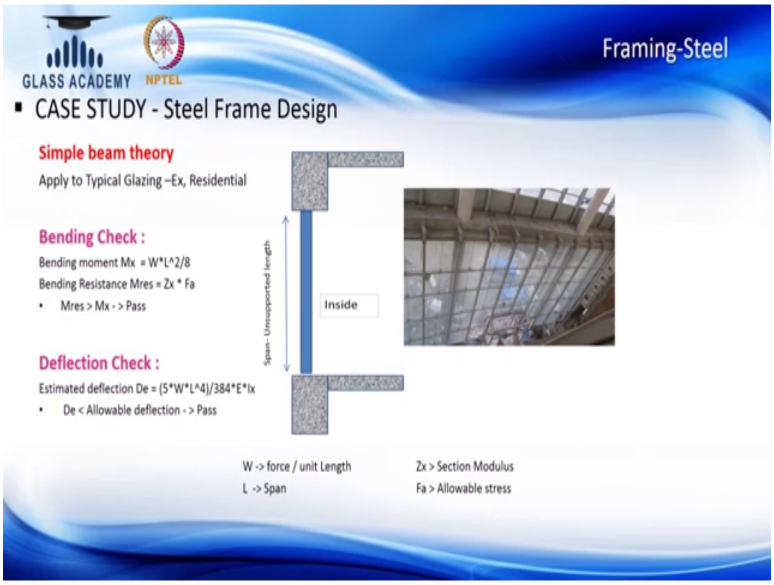
And, the member which is spanning on the longer side which is generally the floor height members need to be checked. If it is a window system the members spanning from top to bottom which uses a simple beam bending theory to check predominately should be checked for bending and check for deflection.

If it is a simply supported check the bending check is W L square by 8 and it is checked against the strength and if it is simply supported the deflection check a simple bending check like 5 W L power 4 by 384 E I. So, these all simple bending check if it is a simple window system; so, the engineer should be aware of its section and allowable stress and the span. (Refer Slide Time: 09:37)



And, if the facade system is for commercial building or it is a curved wall system which is spanning across the floor on the envelope, then it should be check for continuous beam theory which is spanning across the floors. Then, it could be simple hand check or it may need a computer structural analysis.

So, the principle of checking is the same. So, the engineering need to find the bending actual bending moment and with the section modulus the engineer will check what is a resistance versus actual then he will define the pass-fail criteria. On the deflection check for continuous is maybe the simple beam analysis not enough the computer analysis will help you for the actual deflection. (Refer Slide Time: 10:21)



Here in this case is the curtain wall facade system. The beam element is spanning on a much taller height here, it could be 8 to 10 meter if it is a double height entrances and lobbies. Here still the simple beam check is valid, only difference here the span is quite tall, then may be buckling here as combined check is essential on this case.

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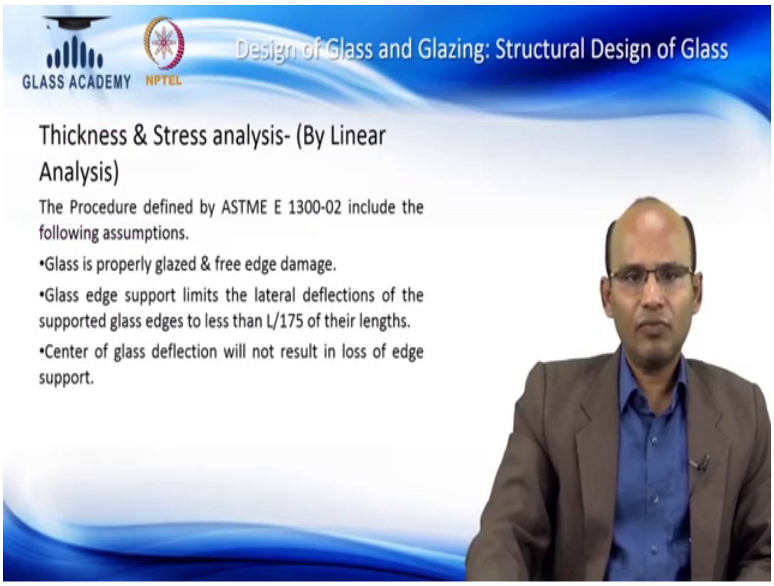

Like a frame analysis we have to do the thickness analysis or stress analysis again is a linear. For glass generally the code is checked from this code or many different international codes. If it is a edge supporter or all the four side supporter is used four side supported or if the glass is only two sided supported the thickness and checking as a different formula.

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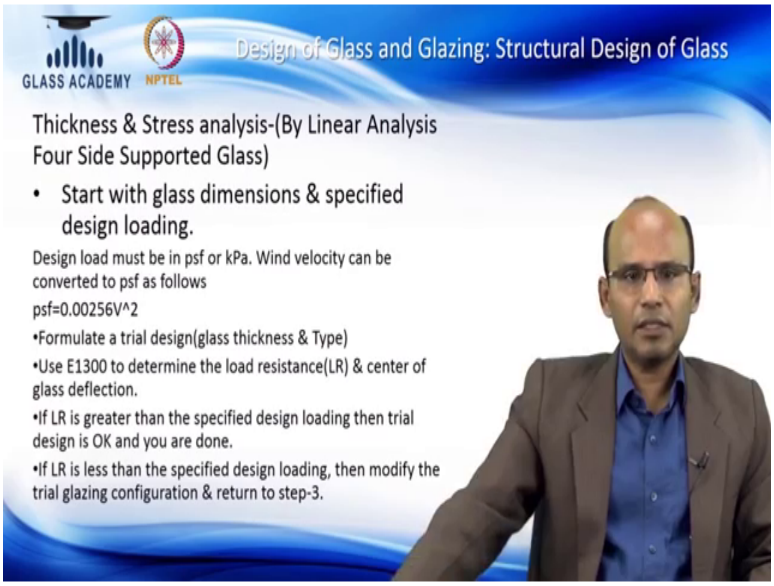

Thickness and stress checking is for as per as linear method on four sided supported glass is using plate design element theory if it is a four sided supported and it is checked either using the codal based a stem E1 300 is quite commonly used or it can be other standard using a plate theory formula.

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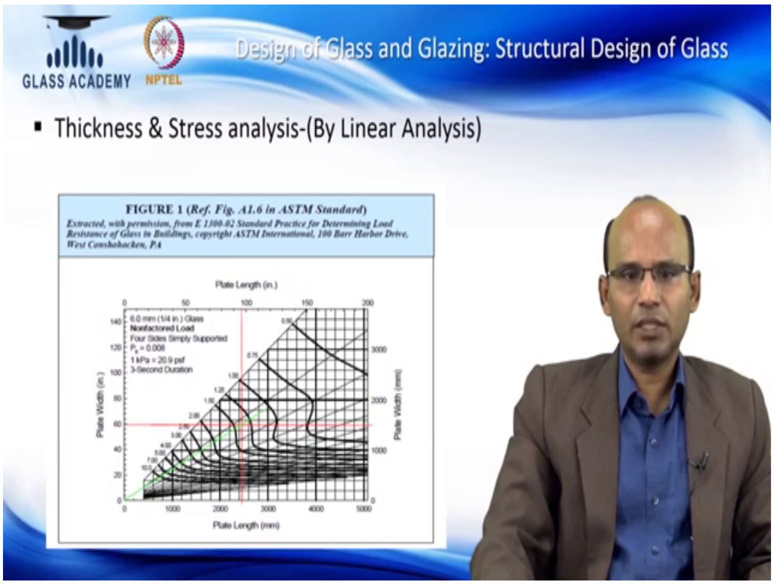

This is derived from the plate theory formula the code has given a graphic which is based on the span the plate length and wind pressure it will give you the glass thickness.

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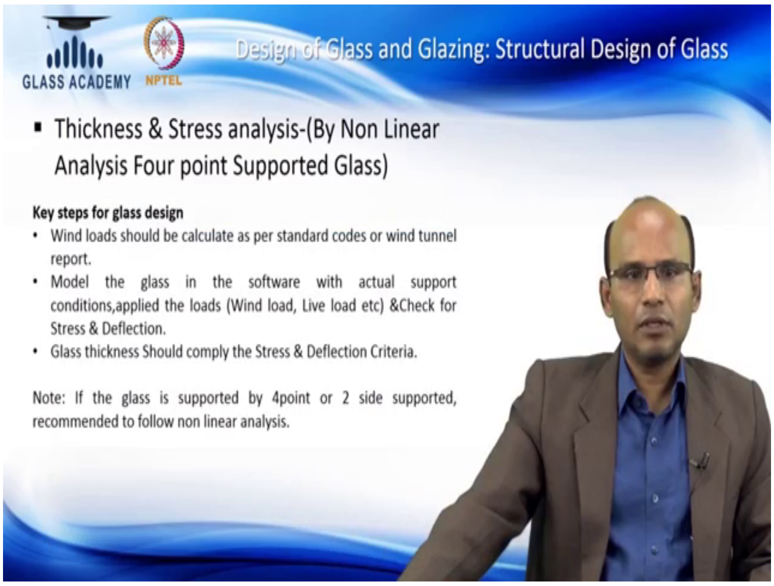

Thickness for the glass for glass design mainly it is defined by the wind loads and it will define the glass based on a whether folk framed support or point support. Here we are checking for a glass point supporter. When the glass is supported on only 4 points rather than framing support this is defined by the 4 points supporter which is using a plate theory, but it is may need a computer analysis.

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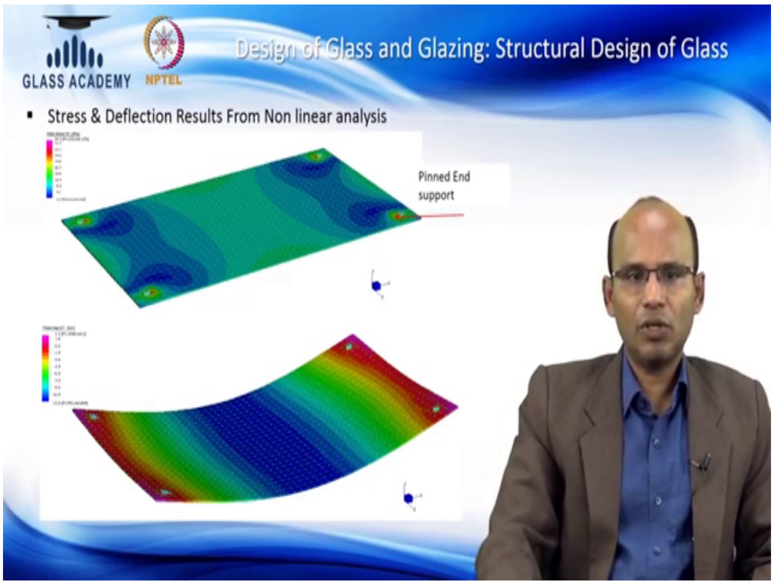

As glass if supported on a point supporter like a frameless glazing or sometime is used for the skylight and roof application we need to check for a finite element or non-linear analysis, so that the glass is only supported on the 4 points. So, there is no over stress on the points and the glass is able to withstand without making a failure of the fixing or a glass panel. And, this generally used to plate theory because of the finite element analysis it need some computer analysis.

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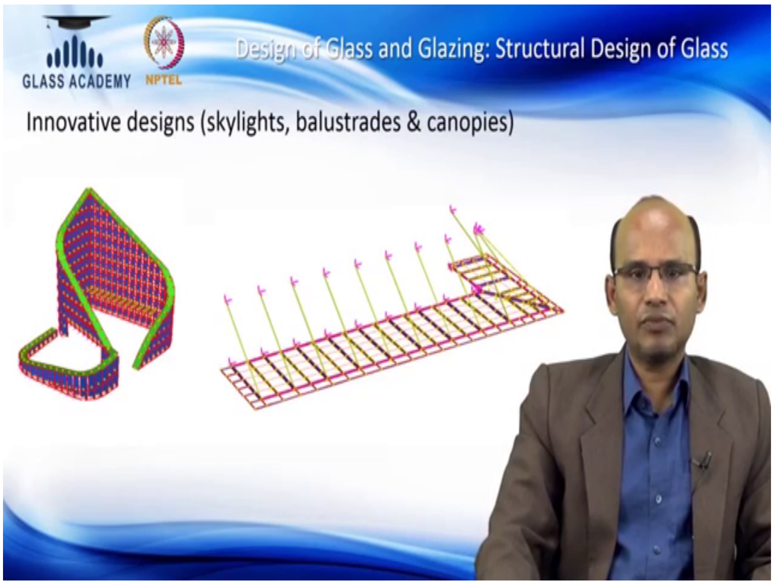

And, there are application facade is used it is like a skylights, balustrades, canopies and here this is used for a roofing application. Here is used for entrance facade is held by the tension rod. We can see it is primary member secondary beam, here the steel design will applicable.

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Design of glass supporting system here the glass is comes in various different forms. It is framed system here or it is here is call frameless point fixed system here. It depending on the system here it is cable net facade tension system here as seen in Mumbai airport terminal T2. And, here it is a panellized system here and primarily this is showing framed curtain wall system or a frameless glazing system. (Refer Slide Time: 13:46)

Previous slides we have seen framing design, glass panel design, cladding panel design. From this slides we will show you fixing and bracketings. A facade system framing elements or supporting system need to be secured to the building here; so, there are various ways it can be fixed as mentioned earlier with the facade systems not a cast in situ. There are different materials bring to the construction building and is fitted to the different levels. Hence fixing is one of the primary criteria which is as a structural impact.

The fixing system structural engineer should be aware and the engineer should be understanding the importance of the fixing system. The fixing system of the curtain wall, glazing, cladding any system need high level of robustness, integrity, good safety factors and it allow a building movements. The in terms of design principle this can be defined a like it should directly transfer the loads any fixing system, it should be structurally efficients the fixing bracket cannot be a over design or too much bigger size oversize it cannot fit into the interface detail. And, the fixing bracket should allow for building movements or rotation and it should be ease of fixing to the within the skills of those at the side.

And, it should be simplicity in terms of detailing it and it should able to interface with the building appropriately. As you can see there are many different ways of fixing system here this fixing system here it shows at the bottom left hook bracket which is fixed with the another bracket here. So, this is one way of fixing here this is good for large building movements sway and used in the seismic zone. So, that the fixing detail is such that is not given additional rigidity or additional moment to the framing fixing and there is another way of fixing bracket here is two panels of fixed with the side fixing bracket detail and which is hooked on to this floor mounted detail here.

This is another good way of fixing here it allowing good floor moment and sideways, so that there is no additional bending to the framing elements here. And, there is another simple way of fixing bracket here is it is a simple L bracket detail which is bolted to the back of the framing detail here. This or do not allow so much of building sway here which is imposing little more fixing restraint here. This bracket can be used on a moderately height of the buildings not very tall and slender building whereas, other brackets shown here this hook bracket details are used predominantly for a high rise building or building is slender and the building has a large floor or sway moment.

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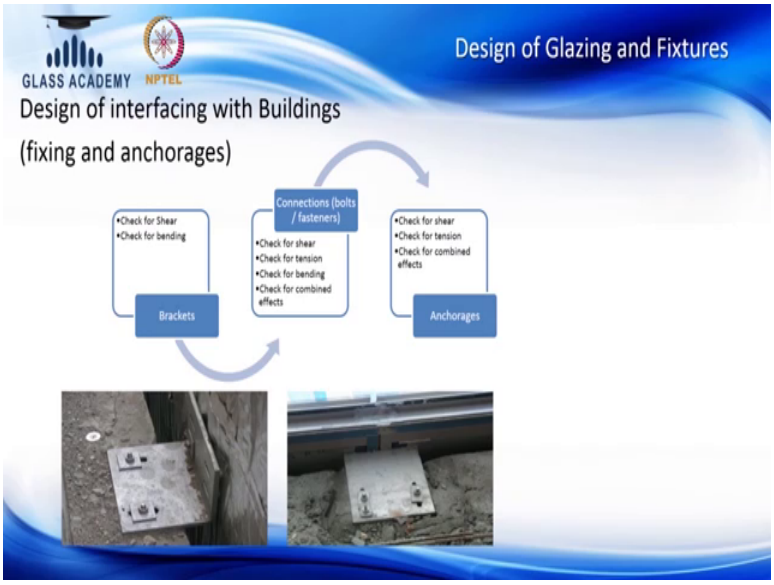

The bracket fixing or interfacing detail is primarily not only the brackets, the engineer should be aware of how the bracket is fixed and how it is interface with the slab detail here. The facade system is running being a windows system or curtain wall system or cladding system. The engineer should have knowledge on how it is interfaced finally, and finished with the building. There is one detail is looking after is a bracket detail and the brackets need to be checked for a shear and bending.

And, they also leave other detail like a connection detail. The facade system mainly made from the metal framing elements. So, it should be checked similar to any steel design like a shear checking, check for tension, check for combined effect. The bracket elements need to be checked for a combined effect on many situation is subject to shear, tension and bending and it need sometime a thick a localised stiffening elements here or it may need a stiffener here.

And, another aspect to curtain wall fixings needs to be checked is anchorages, not only the bracket, the bracket eventually secured with this anchors. So, the engineer should be aware of what is the practical aspects of anchor design should be checked for shear, it should check for tension; anchors here is shown here subject to both shear which is due to the out of plane wind load moment and tension. And, bending will happen due to the eccentricity, the load is here and the anchorages here. So, it has a big overhang extension here.

So, it need to be checked for anchorages combined effect and anchorages it could be a postfix anchor which is drilled to the concrete or it could be cast in situ or cast in anchors. Cast in anchors is embedded during the concrete casting, postfix anchors like this kind of a fixing which is drilled through the concrete or slab or beam then is fixed. So, engineer should have a good understanding of modern techniques of this fixing, the strength of this fixing, the behaviour of this fixing. There are different types of this fixing could be a expansion anchor fixing or chemically embedded fixing or the fixings it can use for a very large tension or dynamic loads.

The engineer should be aware of different way of anchorages and fixing. So, as a combined effect of brackets connection and anchorages which is key essential, which is defining the overall safety of the facade system, if the brackets connections anchorages if any of these elements is failed it will have a catastrophic failure on the facade maybe the panels falling off, something is breaking. So, any small element on this will have drastic impact on the facade system safety aspects.

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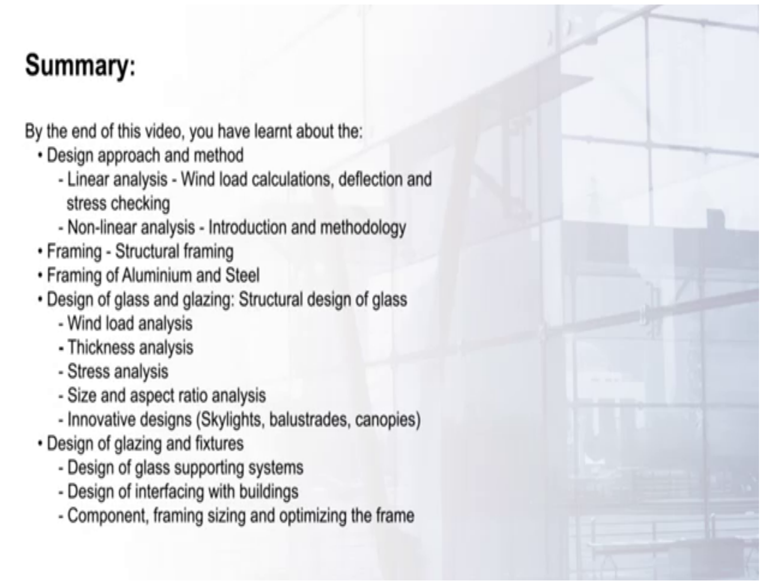

With this we end the session.

Thank you.