Glass in buildings : Design and Application
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Lecture – 56
Glass Application on Facades

We will be explaining little more on Structural Designing of a Glass and Glass Facade. Previously we have cover mostly on application side various forms of application, here we will be taking through little basic structural designing of a glass facade.

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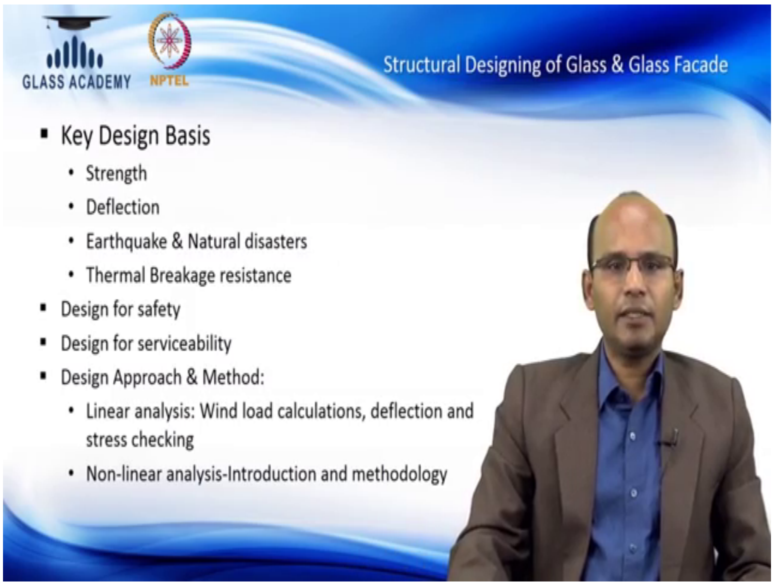

The key design basis of the glass facade is primarily defined by 2 things primarily strength and sometime governed by deflection criteria. And moreover to strength and design there are instances cover by building moments like such as could be earthquake or thermal movement or any type of building moment.

And the basic design principle is design for any it is like any others structural design like steel design or concrete design. The design philosophy is similar is only the material character is changing. So, it should be design for safety and design for serviceability and design approaches when we do the design there design factors are wind load factor, a load factor live load factor there are different factors is considered with suitable combinations. And in some instances the design need to be check for non-linear. Non-linear is critical if you are doing a slender elements small size of the glass fence it is used for last phases the slenderness ratio is too small then slenderness factor is critical.

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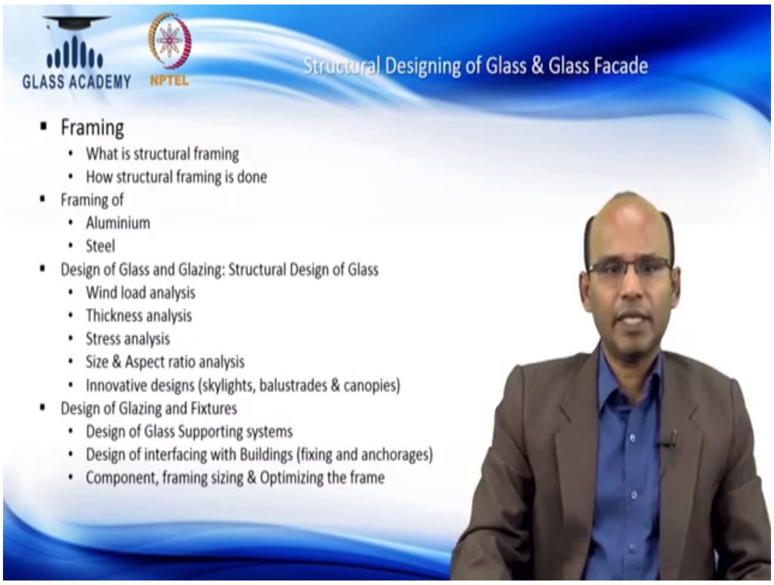

The framing design: so the first thing we start with the facade design or glass design is; the primary member which is supporting the glass in places of framing. The framing is define primarily like any structural elements like aluminium or steel. And how the framing is done how it is getting fabricated what is availability which define the design. And a design of glass facade designs primarily like you are assuming the wind load or calculating the wind load and checking the thickness of the glass material or supporting frames. And checking for a stress analysis and there are instances you will be checking for a specific applications like a skylight application or hand railing glass railing application where the it has to be considered for human impact load.

So, it depends on the application. And in terms of glazing and fixtures is supported sometime by framing in a way sometime it supported by just a point fixing. So, we should be mindful of how it is supported.

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The 4 factors we primarily checking for a facade design a strength a make sure it is safe and it has adequate a safety factor deflection and to make sure it is deflecting. And it is working in still serviceability and safe to accept the deflection seismic earthquake or some more natural climatic conditions and building moments. So, this is more critical for a large building tall building a slender building using curtain wall glazing where the glazing is spreading across the building where this building moment is more critical.

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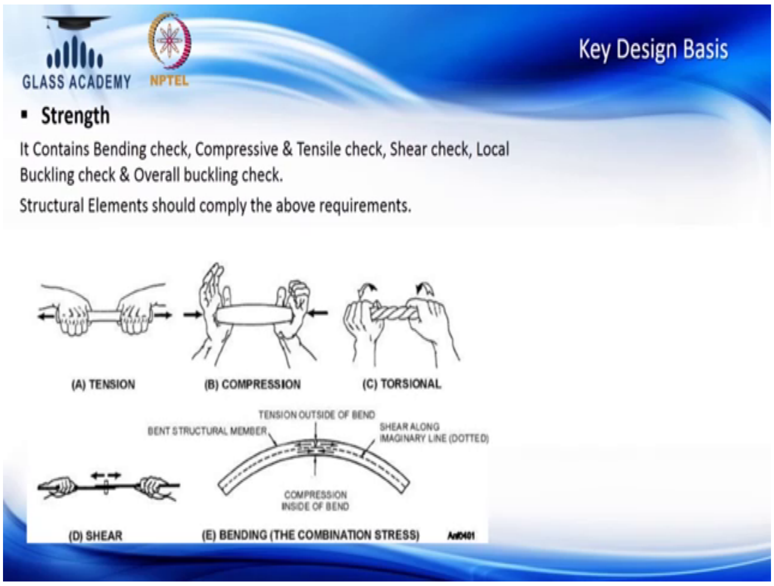

We are going to explain more on strength aspects of the facade or glazing design the; this is primarily applicable for supporting framing elements of facade structures like a framing element is in most of the case it is either steel frames or aluminium frames. So, there we have the designer need to check for tension compression torsional or in many cases combination of all these 3 aspects. Tension is yes, you have pulling force of this member. A compression is it is like column design the stress are getting compressed. So, this in this case you have slenderness factor is more critical. And torsional, torsional is in many cases is critical if the building individual floor height is like a 4 meter a 3.5 meter.

And it has large span of unsupported length where torsional is very critical. And shear primarily checking for fixing connection it is and brackets and. In many cases the curtain wall or glazing member subjected to combined action of tension compression torsional or it could be compression and torsionals. So, the designer should able to understand clearly that at action and where is this check is critical.

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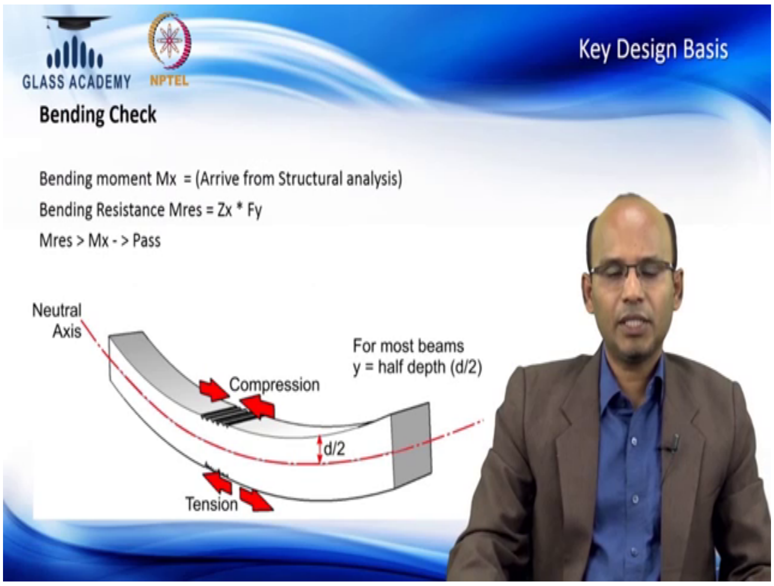

Bending check, primarily bending check is applicable to the framing element which is supporting the glass panels. It could be vertical framing elements or horizontal framing elements. The bending theory same any beam bending theory is applicable. It depends whether this member is simply supported or it is continuous.

If the glazing system is going only from floor to floor it is not vertically continuous then the members can be designed as a simply supporter bending element. So, most of the cases in that case if the beam is vertically supporter, it is simple bending theory like w a square by h is applicable, which is bending check. Bending check is you are checking the compression and tension to make sure the member is structurally is safe for both criteria.

Because the check for positive and negative in load the member need to be checked on both directions.

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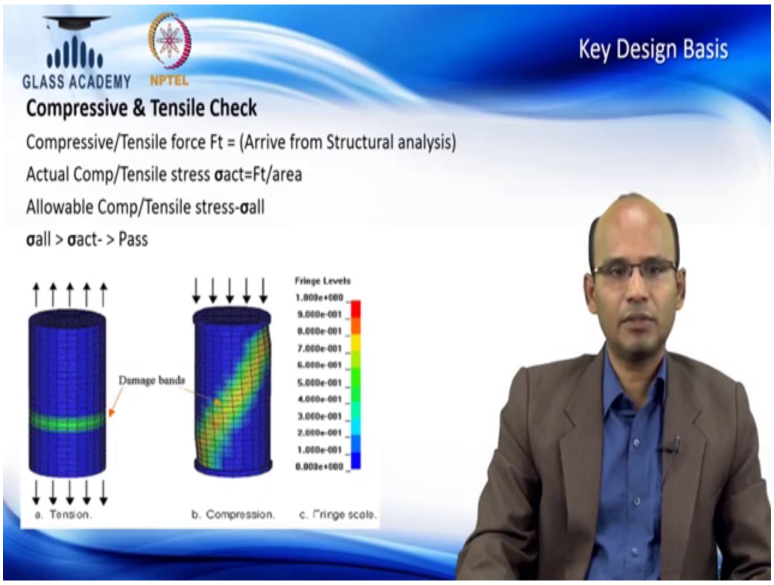

This is check: check is critical for compressive and tensile check. This is critical for a large element or maybe sometime the framing is used for continuously for quiet number of floors continuous there a compression is critical. Compression is critical as a structural engineering knows when certain element is weak in slenderness ratio. So, as a engineers they have to check the slenderness ratio if that falls under like a semi compact or slender then this more detail check is required.

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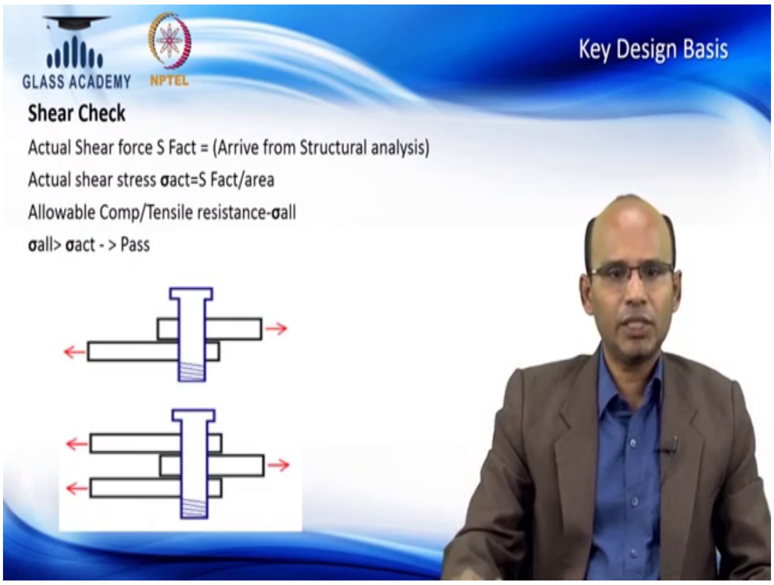

Shear check generally check for connections brackets where the components loads large loads or transfer in a small component, where this kind of shear stress is critical. This is critically if that especially using aluminium brackets. Aluminium brackets as slightly lower bearing stress and bending stress compare to the steel. So, the checking this checking is critical for facade and glazing applications.

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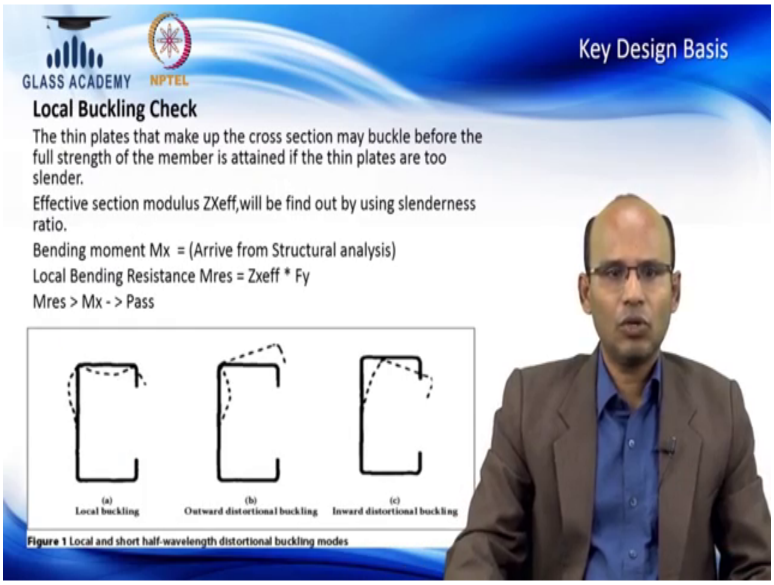

This is local buckling check is critical in glazing system the most commonly the elements used extrusions or aluminium framings. It has thin wall thickness like one mm 0.8 or 1.5 mm thickness.

In these cases, this buckling check is critical, because it is quite common to use slender elements on facade systems. In that case it could fail in local buckling or it could fail in overall buckling and it could fail in combination of local and overall buckling. So, there are detail checks and with various standards available to do the buckling check the buckling check is critical on most of the facade systems.

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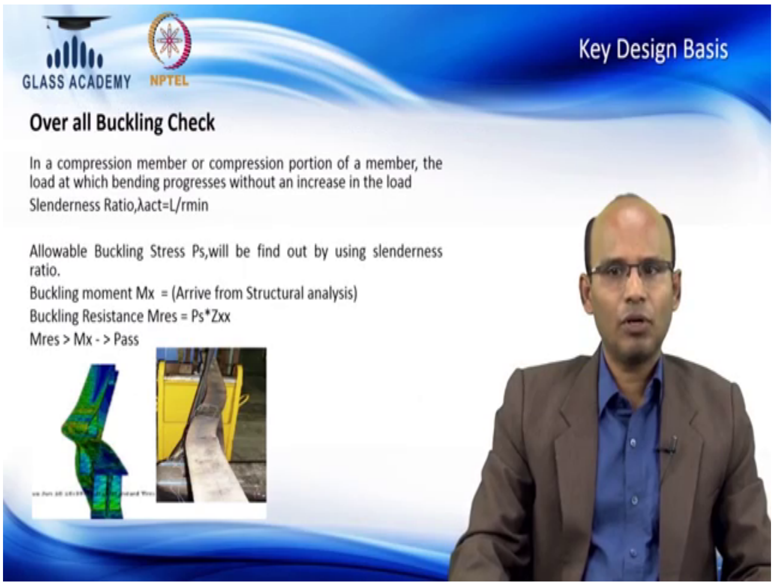

Overall buckling check is something similar to the steel design, if we are comparing to the I beam or open section c channel. It is not a closed section like a hollow section in this case is similar to the steel bending theory. We may have to apply this to the aluminium design.

There are checks available based on slenderness ratio with the slenderness ratio is very small then it is critical to check the buckling check similar to the steel I beam design. The buckling check is as different formula to check if it is compact section semi compact slender elements it depending upon the aspect of this member the various formulas is given in analysis course.

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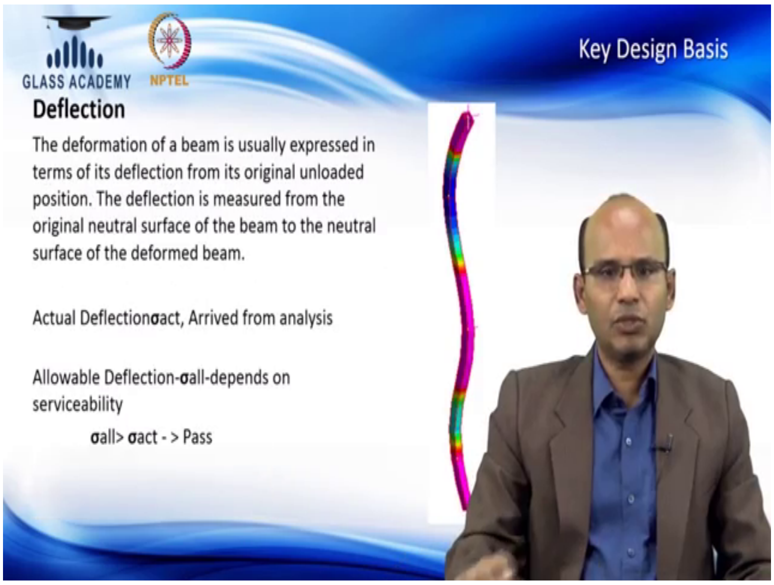

We have been so far checking for strength. Here we are checking for a deflection. A deflection check is critical to make sure the member is deflecting as what a engineer is assuming.

And this is going to be deflecting for wind loads or sometime it could be for a live load to the members glass and glass elements need to be check for these different criteria is primarily driven by the wind loads could be a negative wind load or positive wind load. Here we are checking for a deflection of deflection check is needed for glass and glass supporting framing elements. A diffraction generally follow the beam deflection theory for a framing elements and for glass checking it follows a plate analysis theory for glass checking.

The beam deflection theory it could be either continuous beam or simply supported beam if it is more complex it require a computer analysis. So, that the behaviour of the beam is able to predict correctly. Like any other structural element you there is allowable deflection criteria is specified. Allowable deflection criteria is specified mainly for serviceability conditions aesthetic conditions as defined in the design of this elements. And actual deflection is predicted then the engineer need to check actual deflection is within the allowable limit then this framing elements are members is considered as structurally adequate.

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We will be talking little more on other impact of this facade or glazing system. This one other aspect is natural conditions or seismic or it could be different things like a building movement on many different aspects. In particular, to seismic how it? in fact, the facade system we can study little more detail the seismic has many different impact on the facade as we all know the seismics induce lot of building movements. Sometime the building is accelerated too fast and the material which is attached to building may not able to sustain or take this additional loads.

And it could be imposing the seismic could be imposing on a very tall buildings like inter storage drift or sway beyond the limits. And seismic could also impose lot of different shaped building movement. It is like one floor is not moving the upper floor or top floor is moving too much movement. And the seismics put lot of dynamic load to the building envelops framing or glass element. And it also gives so much of additional loads to the serviceability of this framing system bracket system the glass cladding panel which is supporting.

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Continuing with the loads relevant to the building (Refer Time: 12:20) or could be seismic on earthquake. The predominant force which is imposed on to the glass panel facade system is in plane forces, but you can see here when the building is drifting or swaying, it is going to put the horizontal loads on this glazing element. And this system need to be verified for in plane load. As structural engineer should be aware the facade system or it is material is very strong element in supporting the out of plane loads like a wind load which is acting on a plane. It may be weaker on it is own plane on this minor axis loading. So, the buildings sway may impose minor axis which need to be checked during the design.

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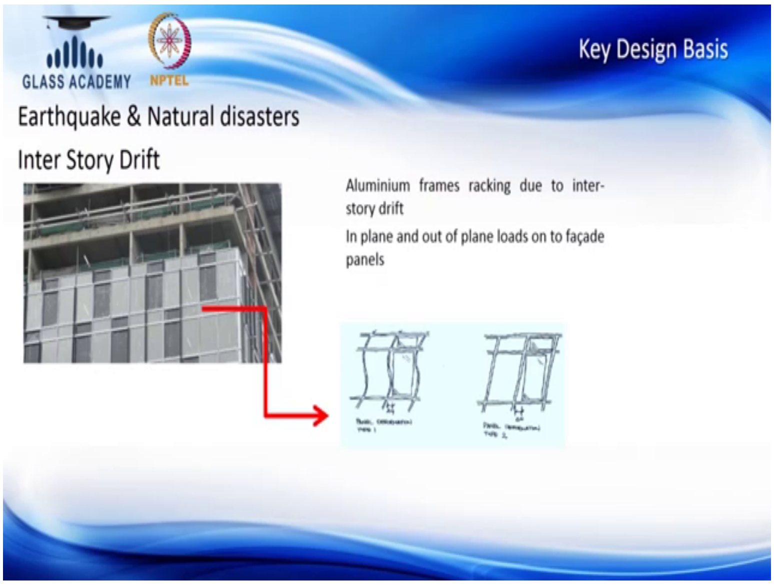

Here we are explaining other impact or the framing how the framing will perform if the building is swaying or drifting. It could be due to earthquake or due to the just a wind load or sometime even a gravity load. So, the building high rise building we all know it will sway on it due to that height of the building or slenderness factors of the building, but this building sway how it will impact on the glass facade if the framing it could also give a various modes of acceleration. It could the frame could have this kind of a impact or it may be linearly leaning towards this.

So, when the frame moves it will put lot of stress on the glass panel or any other cladding material which is holding this as a structural engineer they have to check this.

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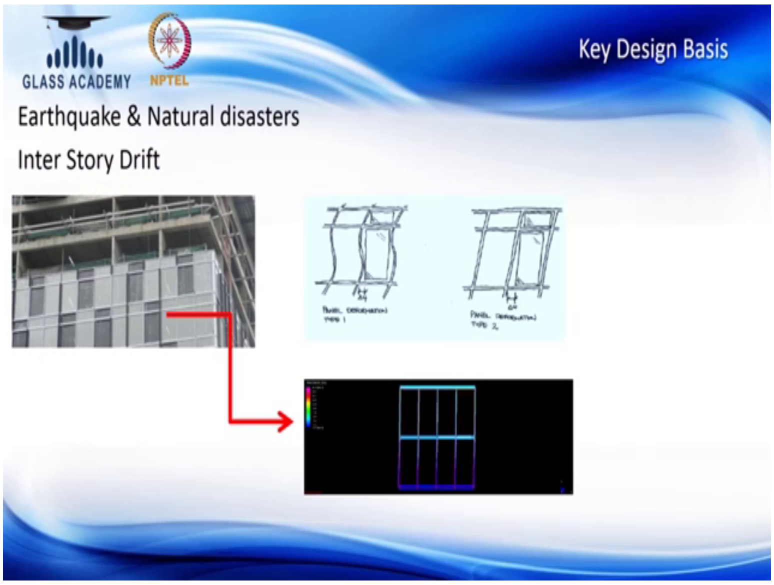

Here we could even little more detail video showing how this building sway you will impact the framing elements in particular, as you can see the building swaying when the framing changes to red. It is highly stressed as you can see this frame is imposing lot of loads on onto this members when it is swaying you can see here which is this video is showing primarily this linear sway condition.

This condition the frame will have more impact relying on that weaker axis bending.

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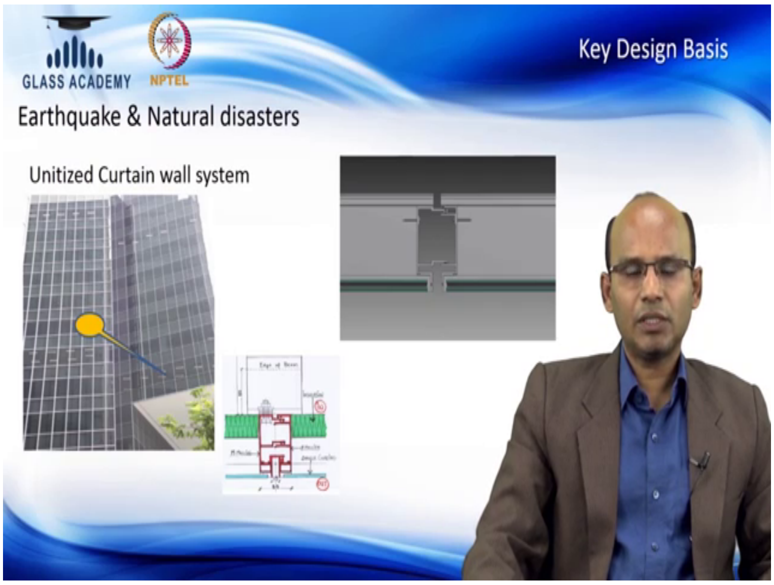

Continuing with building movement the facade system you can see a typical section detail of the facade system the glass here. And it has a framing arrangement and there is a bracket which is holding these panels. So, this is a primarily if you take a curtain wall glazing system for a commercial building generally this system is adapted. You can see is a glass building the glass is used at this level when you see from the floor level is different. At the face of the beam it has a darker band here which is using a different glass combination.

But the system is, it is a prefabricated is called unitized curtain wall system or prefabricated panellized the system. Each glazing panel you can see prefabricated and it is fixed to the building with the bracket here. And this is a fixed with interlocking arrangement of aluminium extrusions. This is no limit on the extrusions shape design in it is quite common to you customize these faced based on individual project needed. And this video will explain you how it is moving horizontally. In our previous slide we have seen the building moving sway, when the building is moving on a sway this is will impact on the horizontal movement of this joints.

And continuing with this the moment when the building is moving be the engineer need to carefully check the joints. Unlike other building materials like concrete wall there is no primary joints on the surface except where it is interfacing, but curtain wall or glazing or cladding has lots of joints along the face of the building. Hence, the joint design is one of the critical here the joints are needed mainly for building movement or thermal movement for various natural conditions there should be a good joint design. So, that the joints are not cracking or failing during the service of the building, and there should be two way of doing a join design horizontal joints and vertical joints.

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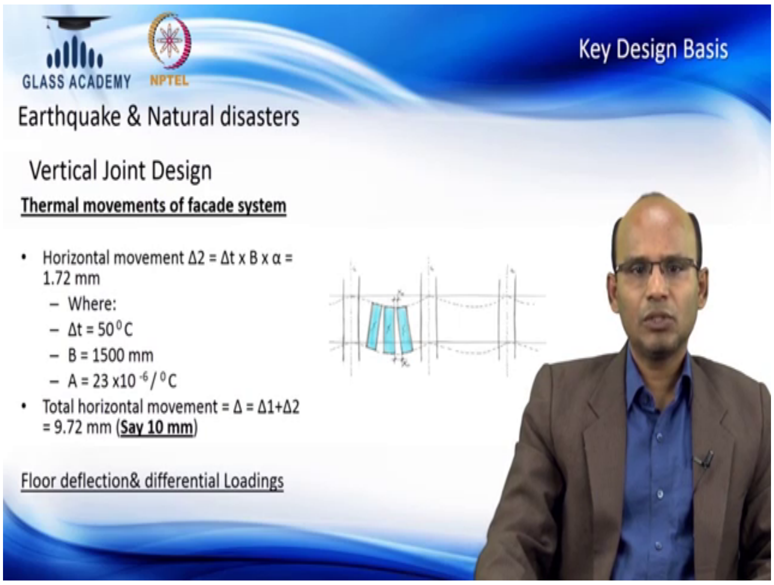

Vertical joints is mainly on the floor horizontal joints on the panel joints. This calculation is showing how do we design a thermal moment. Thermal moment for any glazing system is primarily effect of change in temperature which is delta t and what is the width of the panels. So, how wide is the panel, if the panel is much wider and it has to move lot of a horizontally and the thermal expansion. So, this simple formula here we will show you the horizontal movement required for this curtain wall glazing system is around proximately 10 mm.

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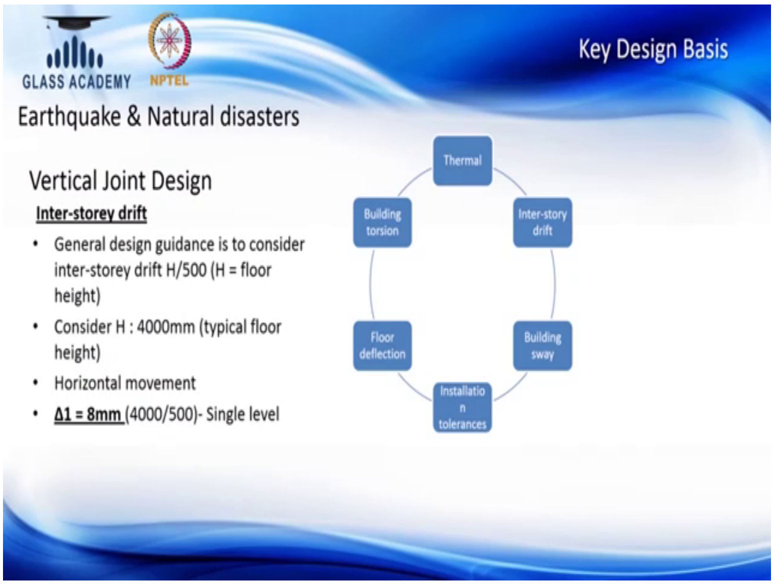

Similar to horizontal design it should also be checked for vertical design. Vertical design is critical if the curtain wall is going continuously to the tall building and it is passing several floors above. And it should be checked for 2 things vertical horizontal movement and as well as inter story drift. Inter story drift is mainly from a floor to floor drift is happening on the side ways due to the building sway. A lot of standards is allowing this like a h over 500.

So, floor height divided by 500 which the engineer need to be understanding this requirement. So, that he can design the joint such that it will not crack or a fail during the building moment. And the joint design needed primarily for this factor it could be due to the thermal inter story building design and installation tolerances, because it is most of the facade system it is not a casting in situ a various components coming and is getting fixed the site.

So, the engineer should be aware of a tolerances. Floor deflection the floor will be deflecting due to the live load or in some cases if the slender building, then the torsion maybe a critical factors for a joint design.

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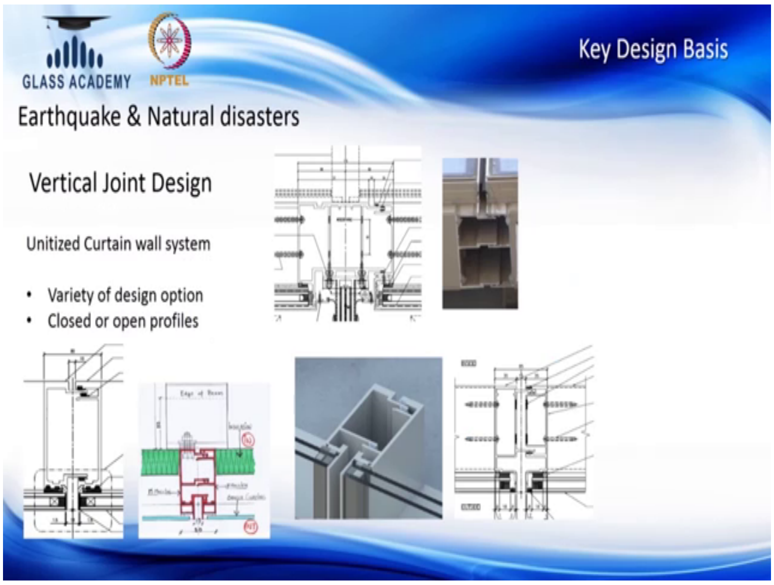

It is still we are continuing with the joint designing facade system has no definite rule for using the particular standard profile unlike a steel design. In steel design we have a standard profile like a I beam c channel section channel section angular section or hollow section, but curtain wall the engineer should be familiar with what is availability and what is possible what is a limitation here.

And you can see in this the profiles which is supporting the facade or system has no definite shape of the profile it could be a many different shape here. And the primary concept here is the there is aluminium framing which is supporting the glass. And the glasses supported with structural sealant or it may be some time has a mechanical fixing. And the shape of this aluminium profile could be very different from project to project and each panel shape is defined by many different factors it could be a opened section like c channel here or it could be a hollow section here.

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We have just passed through the vertical joint design this slide is showing the horizontal joint design.

The horizontal joint designs primarily happening or the floor joints here or it could be somewhere in between. And this horizontal joint generally happen mainly it follows the floor slab of the or beam level of the building. And you can see this is the picture is taken an actual project site. On a curtain wall this is a joint if this is a floor here what you can see this u type of like a channel profile is sit fixed at the bottom there is one more profile which is coming at the top. And what it does here is different panel is fixed. So, it allows panel to move as you can see in this video the panels need to be moving vertical direction here and this vertical moment will take here of that floor to floor movement.

And you can see the panels here is not moving panel above is vertical sliding. So, it is it is called vertical joint design.

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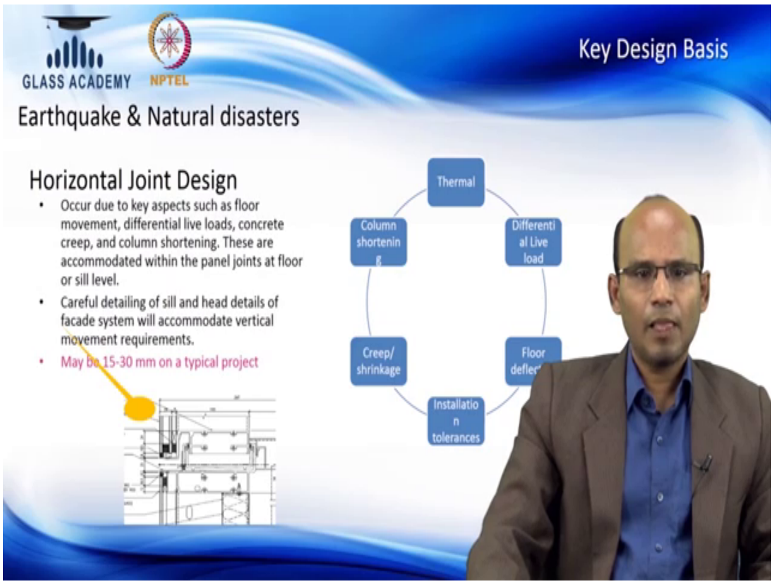

Horizontal joint design: this is same detail as we have seen previously the joints need to be taking care of the same aspect differential live load floor deflection insulation tolerances. The horizontal one more aspect is critical is that a creep or shrinkage and column shortening this is a long term. This 2 are long term effects which will impact the framing elements of the facades. So, the facade systems need to be designed for joint design.

Typically, if you combine all these impact the engineer should be aware apart 15 to 25 or 30 mm is need to be design all the horizontal joints. So, that will define how the joint design is designed for the project.

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There is multiple ways these joints are design, it could have the capping here it has no capping here or is just exposed glass joint here, but the principal remain same here there will be a joint here the glue line joint here. You can see this picture has a different joint line here. It primarily allow the horizontal panels of moving so that the glass panels or cladding panels not cracking due to the building moment.

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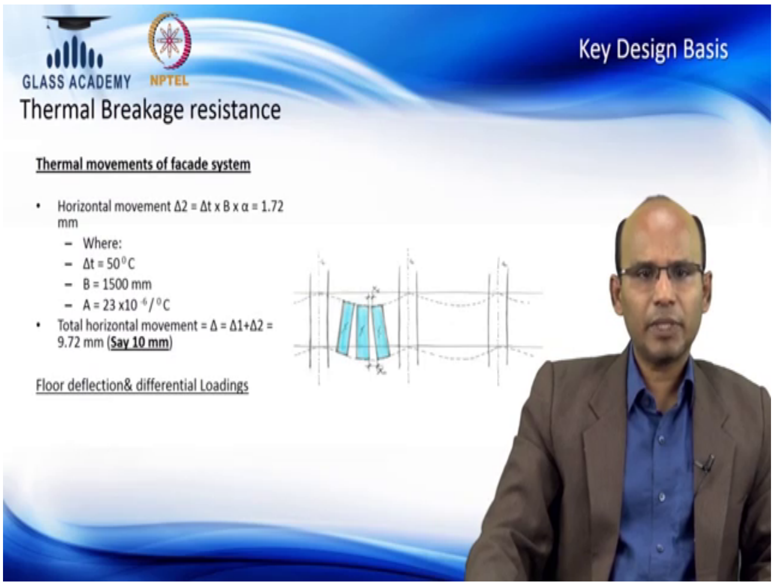

Another aspect of thermal movement that we have seen previously here is thermal movement design it is the same formula is adapted here. Delta t times panel and thermal expansion. So, the engineer should arrive and make sure he checks for combination of floor moment and vertical movement.

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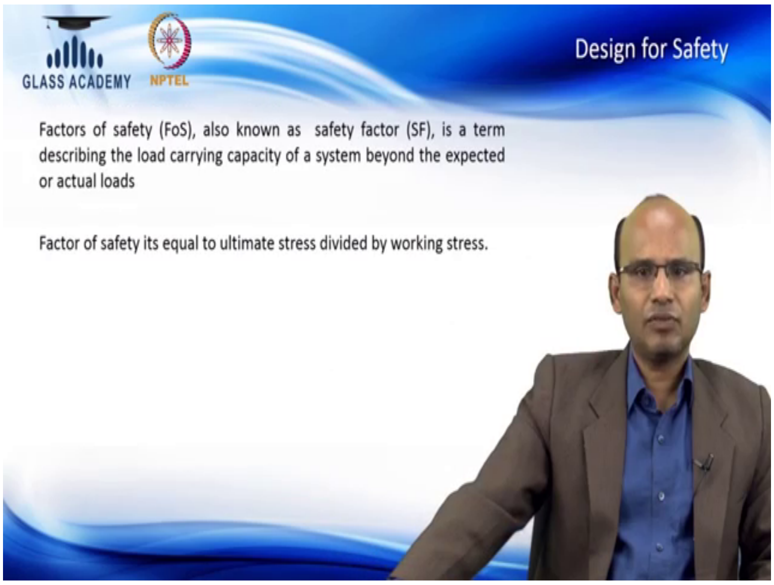

A factor of safety as typical to any other steel design or concrete design is applicable to facade elements being and glass cladding panels or framing elements as bracket detail. The safety factor is for a framing elements is generally 1.5 time of safety factor and for glass element the safety factor is much higher like 3 or sometime 5 it depends on the glass types or which standards is being used.

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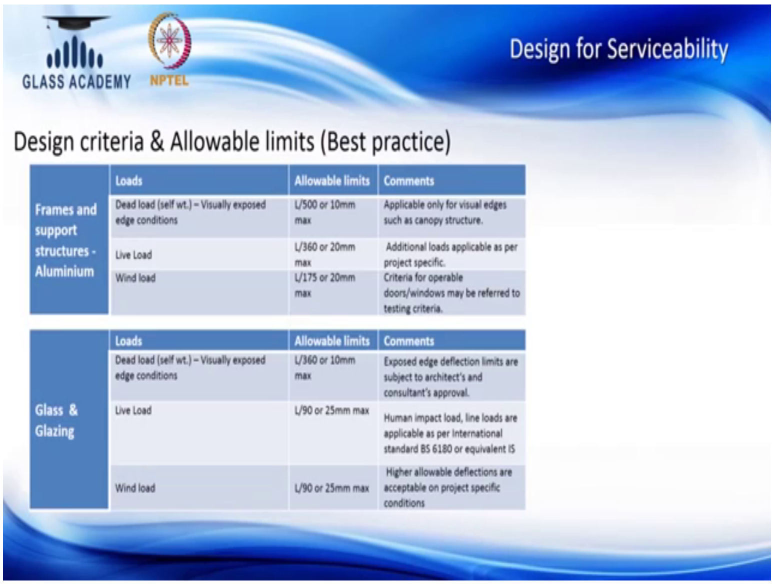

The general design criteria or may you call as a best practice for framing elements. The framing elements on facades is generally aluminium framings this 3 different types of loads is applicable here as dead load mainly the glass panel or a cladding panel. Live load just due to that the glazing element or impact to the human load or if it is used on a skylight there are maintenance load human loads to be consider and wind load. Wind load for frame elements is given an allowable deflection criteria span over 175 or 20 mm maximum, but again this depending upon where it is used for windows system or if it is used on curtain wall system this is different.

And this is slightly a less strengthen as compared to a steel design generally span over 240. Aluminium has is much more ductile materials compared to the steel. Hence, the allowable deflection is given much more higher. So, as less strengthened as compare to steel deflection criteria, and a similar to the framing element here it shows the glass and glazing element or cladding element.

It has dead load criteria mainly dead load criteria is not a major factor. It need to be check for a wind a live loads; if it has a human impact such as glazing used at the lower level the seal level or the hand railing glass railing this is critical. For wind load checking glass deflection there is no definite control of the deflection the reason being deflection control is not something or a safety concern. It is more of serviceability aesthetics and a perception.

So, there is no definite control on the deflection as a industry practice it is taken like a span over 90, or 20 mm maximum allow, span is consider as a shortest span or whichever the span is the glasses deflecting.

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