Glass in buildings : Design and Application
Prof. Jothi Ramalingam
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 66
Performance Testing for Facades

Hi, greetings. I am Jothi Ramalingam from a company called Winwall Technology India Private Limited. Today we are going to discuss particular topic called Performance Testing of Facades. So, before we go into the topic, let just understand; what is this word facade mean. Facade is if you look at the English dictionary, it is the exterior of a building or something that is used to cover a building to make it look good.

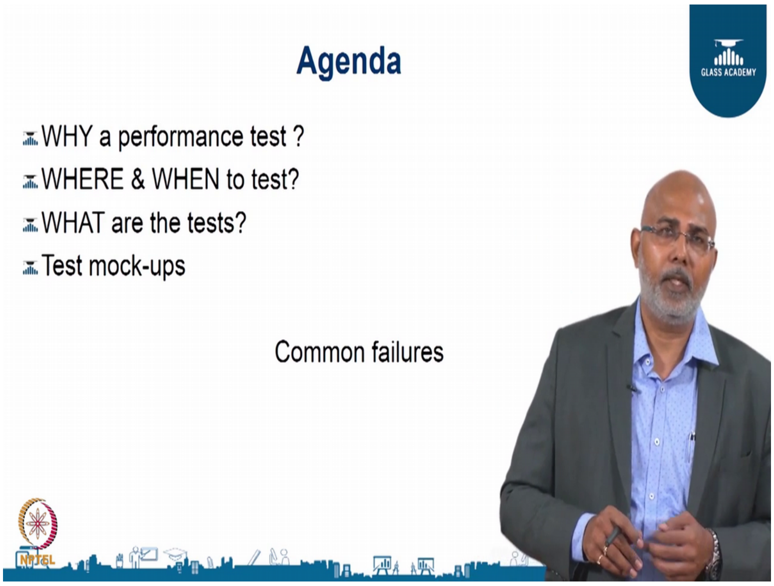
So, now as we get into the modern day we find that we want to look, I mean, just the way we have changed our dresses. The buildings also keep changing in line with the technology that has been constantly moving upwards. And because of the pressure on the space in urban locations, it is become very I mean it is very important and there is no space available. So, the only way we can move is vertically, because the quantum of population which is moving into urban spaces there is such high pressure on the urban space that, the only way to move up and leave is go up vertically. So, we find that we have taller and taller buildings.

Now, as we get taller and taller buildings it becomes more and more critical that whatever is used on the taller buildings also are extremely safe, and they perform to certain characteristics certain parameters which have been defined over a period of years. And you know, so we are now going to find out what those parameters are, and how do we actually test the facades to understand whether they are performing to a certain standard or not.

Testing like all we know all of us know every product that we use in our day to day life, right from the pen that we use or even the mobile phone, it does not come right from the design stage into the market. It goes through several variable models and prototypes and testing for certain parameters. And then finally it comes to the market. In the same way facades also come to the market or come onto the building after going through a series of test, and corrections and you know fine tuning to ensure that the best reaches the building.

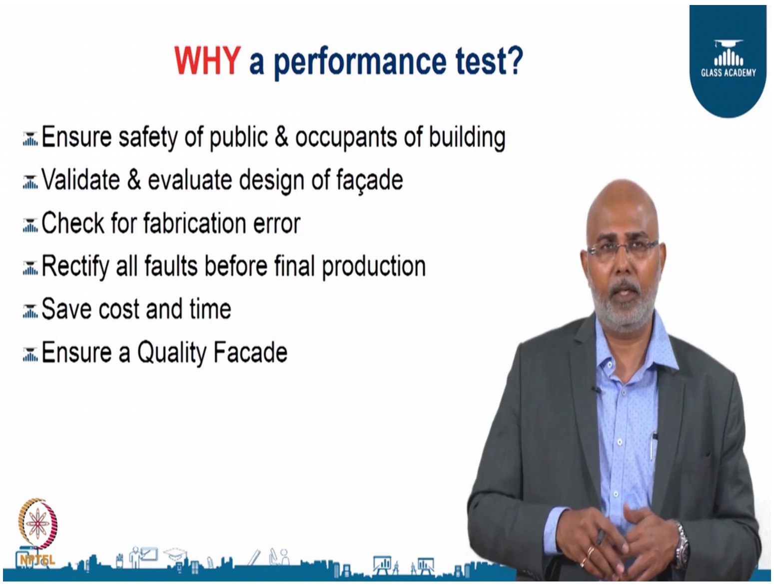
So, let us go in to the subject of performance testing for facades.

(Refer Slide Time: 02:59)



So, the first thing that we the question that we ask is why do we need to do a performance test, and where and when do we need the test, and what are the different kinds of test. And some photographs of test mock ups and of course what are the common failures that we see and how do we address those common failures.

(Refer Slide Time: 03:21)



So, why do we do a performance test? The first and foremost thing is that it is to ensure the safety of the public and the occupants of the building. Now as you as I explained earlier you know the buildings are getting taller and though and so, the cost of the failure is actually going to be very heavy. If you are living in a ground floor apartment and something falls not much of a damage happens, but if you are living on a 30 storied apartment or 30 storied building; where your office is and one glass panel falls from there that the consequence can be quite disastrous to you know property and human life.

So, in that sense it is very, very critical that whatever is going to be used there on the top has to be put through certain vigorous test and ensure that it is fail proof. At no point of time given whatever wind loads and the worst cyclonic conditions it should not fail. So, that is one of the important things you know public occupants of the building and the general public around the building.

Validate and evaluate the design of a façade. Now basically nowadays it is not that people use a standard product on every building. Every architect wants his building to be unique. So, the shape of the building is different, the size of the building the way it is built the architecture everything is different. So, for every product every project there is a specific design that is coming into play. And so, the extrusions which are being used as the framework is specifically designed for that project for the height of the building depending on the wind loads and depending on the specifications at the architect wants from that building.

So, it is all theoretical they have they are using a lot of theoretical calculations to arrive at the structural profile and the design. So, it is before it is actually mass produced, it is always better to validate the design by actually doing a test on a real sample, understanding how it is performing if there are certain small corrections to be made, get this correction done retest it and then go for the final production.

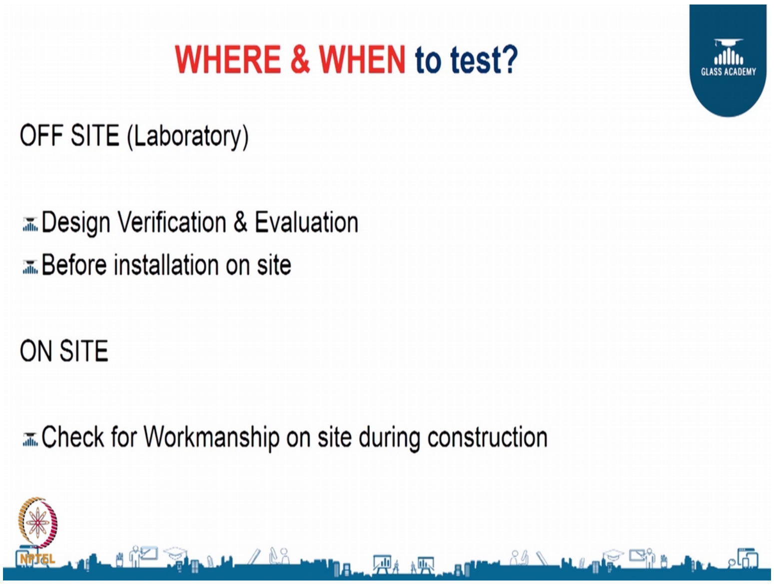
And then the third one is the fabrication error, now the design may be fantastic, but the actual fabricator whose going to fabricate that facade and install it at the site; whether he has the qualification and the capability to actually understand what the architect, and the designer of that facade had in mind, and whether he is actually executing it as per that we need to validate it and verify it.

So, here is a good opportunity to actually do a small sample, test it and then there you can test the quality of the fabrication also. And then number 4 is the rectification of all the faults which are minor, you know minor issues which I have been overlooked during the design. If there is found out during the test, then you can do corrective action, make those changes in the system and that will make sure that when the product is finally, being used you know it is a 0 error.

And the fifth one is because of this rectification of all the faults before the final production can be done. So, that we do not have to do any rectification, once it is installed it is very, very expensive to conduct any repairs on because of the height and the accessibility sometimes it is impossible to do any repairs. So, you may end up living with the problem for a lifetime, because the building cannot be repaired, and you have to have there is a watery cover if there is a airily, cover if there is a structural problem you have to just manage with it. For going through all this processes you save a lot of cost and time. Unnecessarily you do not have to waste your effort and money on rectifying a repair because stitch in time, you know, saves 9 we have and of course, prevention is always better than cure.

So, having gone through the tests you know and make the make the corrective action and make sure that this is all the minor errors have been eliminated. And you ensure that the product that finally, coming up is a quality facade which everybody is happy about. So, it get everybody gets value for money.

(Refer Slide Time: 07:45)



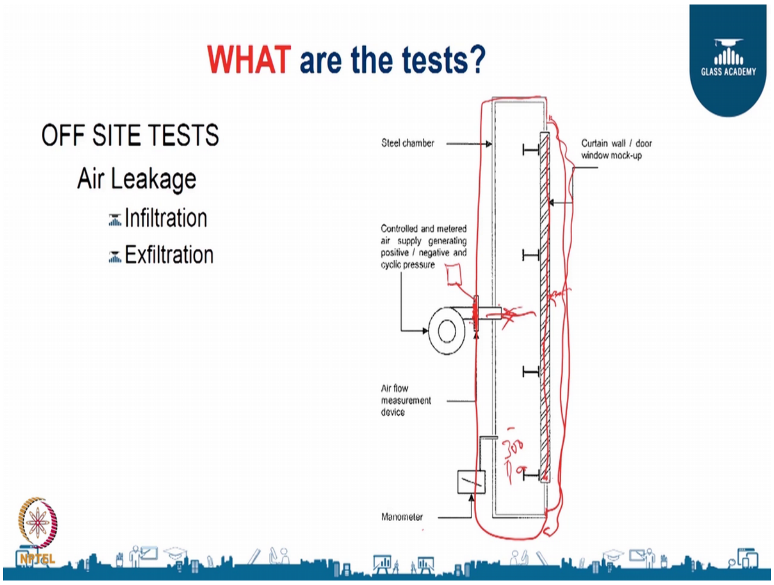
So now let us get into the kinds I mean where do we test and when do we test it. There are basically 2 different locations where tests are conducted. One is in the laboratory and one is at the site. The one that is done at the laboratory is before actually any installation starts ate the site.

So, the design verification and evaluation has done at the there is a mock-up which is installed at the lab, and then the there we create atmospheric conditions to you know understand how the behaviour of the facade. And based on that you know make corrective action, and retest it and make sure the product is perfect in it is design, and it delivers what it is supposed to. So, that is done at the laboratory that is way before the project actually starts in the site. And the other one is the on-site.

So, once the sample is been tested and it is approved it performs well and it is certified, and then there everybody signs of say that you can go ahead and start manufacturing at. So, how do the developer and the architect and the consultant ensure that the same quality that was you know that was used for the test is actually being replicated at the site, because it is a thousand times bigger or may be 500 times bigger than the mock up sample.

So, in order to ensure that the same qualities delivered at the site, there are certain test which are done. At the site as the progress you on a progressive basis as the project is getting implemented, on a random basis to ensure that it is tested and the performance of that at the site is the same as what it was when it was tested at the lab. So, this is to check the workmanship consistency of the workmanship and on the site. It did not just the fabrication, but also the installation process whether they are following the process at the site during installation, because there the fact is that the facade is not one single monolithic product. It is thousands of small panels which are installed one after the other with some cascading and sealants. So, these are all you know depends on the skill of the workmen and the method they follow and the consistency in which they follow the process.

(Refer Slide Time: 10:17)



Now, what are the tests basically there are 3 tests. The first one is air leakage, and façade again is not like you know single huge piece of glass. There are thousand glasses, or 5,000 glass panels; which are coming in a series, vertically and horizontally, they are being installed at the site, and there are thousands of joints. All these joints are getting locked into each other by gaskets.

So, obviously, you cannot have 0 air leakage, but there are certain standards which have been established, and that standard clearly sees how much of air can leak from the facade. So, we look at different standards for leaking. And then in the mock up sample we actually try to measure what is the leak through the sample.

So, how do we do that? There is a process and there is a specification for air infiltration and exfiltration. So, the lower the air leakage through the facade the higher the energy efficiency of that facade is. Because considering the fact that you know we are always having a controlled environment inside the building. We try to maintain a temperature of may be 22 or 24 degrees air conditioned or heating up whichever may at the case may be, while there outside atmospheric conditions may be much more harsher. It can be extremely hot or extremely cold.

So, under these circumstances the quantum of air that is leaking through the facade as if it is minimised and kept as low as possible when the energy efficiency of the building is very, very high and you can save a lot of money. Because sometimes we do not realise that we are losing so much of energy. Because the facade is such a huge area you know which covers the entire frontage of the sides of the building there are thousands of joints. So, even a 3 percent or a 5 percent leak extra means million rupees going down the drain.

So, for that what we do we check, we have a chamber here. Now this is the chamber where we create we have the sample this is the facade sample. And this is the chamber which is made it is already there it is air tight. So, we have this blower and we start sucking the air out of the chamber. So, you have a negative pressure here, say negative minus 300 Pascal's. And this differential pressure is measured by a manometer over here. And as this air is getting sucked out, we are also measuring the quantum of air which is coming out through a airflow meter. This is the orifice plate over here, and there will be a airflow meter which will actually be measuring the quantum of air that is coming out.

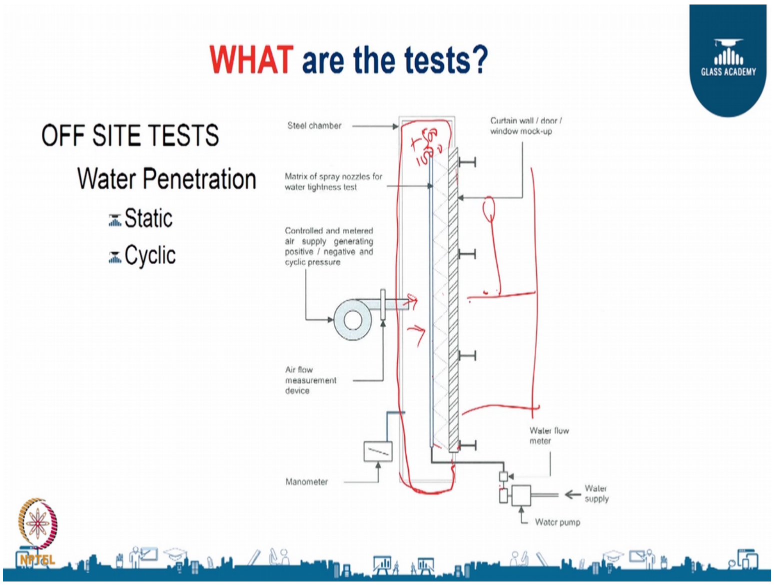
So, at a differential pressure of 300 or 500 or whatever is the specification, when we reach that differential pressure there is a continuous air that is coming out at that constant differential pressure. So, that is the leakage of the chamber which is a fabricator structure and the curtain wall or the façade sample which is been mounted over here.

So now how do we identify how much of this is the chamber and how much of this is the curtain wall? So, what we actually do is we put a plastic sheet before we start the test. And this plastic sheet is an impermeable layer covering the facade. So, when we start sucking there this plastic sheet comes and gets stuck to the surface. So, then there is some amount of air which is leaking over here and this is measured and recorded. That is the actual leak through the chamber.

So, once that is ascertained and recorded, this plastic sheet is removed. Once this plastic sheet is removed we find that there is an incremental flow of air through this air flow meter. So, the difference between the first reading and the second reading is the actual flow through this facade. So, there are specifications for example, a streams is a 0.5 liters per second of air can leak per square meter, which converts itself into 1.8-meter cube per hour per meter square.

So, if you have a facade of 10 meter square; that means, 18-meter cube per hour is allowed as a leakage. And there are of course, special allowances extra allowances given for openable where the perimeter length of that openable is taken and then some extra allowable air is provided for as an acceptable tolerance. So, this will and then exfiltration is the exact opposite of infiltration where you start positively pushing the pressure into the chamber and again measuring the airflow in the same airflow meter. More or less the in and infiltration and exfiltration volume of air going through the facade is more or less you know equal. So, in more test it is only infiltration, but some consultants also want to check the exfiltration all.

(Refer Slide Time: 15:31)



The next one is the static water penetration test. Now one of the things that the facade is supposed to do is to stop the water from coming in when there are extreme cyclonic conditions or a typical monsoon that we are going through. Now we have a huge glass facade in the front and then there is expensive interiors which has been done and there either a house or an office there are fault sealing installed and then we have lot of cabling going in this fault sealings and networking cables and electrical cables. So, you cannot afford to have water coming into the building and leaking through that, because there can be a (Refer Time: 16:09) you know accident, we can have a short circuit or you can have fault sealing being a gypsum it will fall down on somebody's head.

So, in order to avoid that, we have to ensure that this facade is absolutely watertight. And there no water no chance of any water entering into the building. And because if there is water entering into through the facade is extremely difficult you want to identify where the source of the leakage. But in generally water tends to go in the path of the least resistance. So, it can interact some level you know on the fifth floor and come out at the second floor. So, it is very difficult to identify where the water is actually entering into this façade.

So, again to check that what we do is to we have a you know again the same sample, with there is a array of nozzles which are spraying water. This shows actually this is as per the Australian standard; where the inside of the building is this side and the facade is actually kept upside down, and you spray water over here is a array of nozzles which is spraying water of around 3.4 litres per minute per meter square. And this is actually controlled by a water flow meter which is you know depending on the surface area of the sample. The water flow is controlled and these are uniformly located like, the distance between this nozzles are uniform vertically and horizontally.

And your you are going to have a manometer to create a differential pressure and here, because the water uh this thing flows from the inside as per the Australian standard. We are starting to blow air from here into the chamber; so, this has a positive pressure. So, once this pressure builds up and this water is continuously being sprayed, people are standing over here and observing on this side in a platform, here and here let say.

So, you see if there are any water leaks coming through this. The pass fail criteria's very clear, and no water leakage should come through the facade, absolutely at the differential pressure of maybe let say 500 Pascal's or a 1,000 Pascal's which is created here, and this water is being constantly sprayed for 15 minutes. The test is for 15 minutes, this chamber becomes airtight, there is a door which is you know sealed and you close the door and then start pressurising from inside with the water being sprayed. There should not be any leak on this surface, on the outer surface.

So, this is the static water where you have a constant pressure differential pressure of 500 Pascal's or a 1,000 Pascal's maintain for 15 minutes. And at the end of 15 minutes you stop the water flow, if there is no water leak it is a pass. The other one is something more stringent which the Australians have a specified, wherein you have something called a cycling water penetration test; where cyclic you create a you know cycling pattern of the air pressure. So, you increase and drop the pressure in the cycling pattern between 3 stages. The entire test is 15 minutes the first 5 minutes basically you have like 15 percent of the design load, 2 30 percent of the design load.

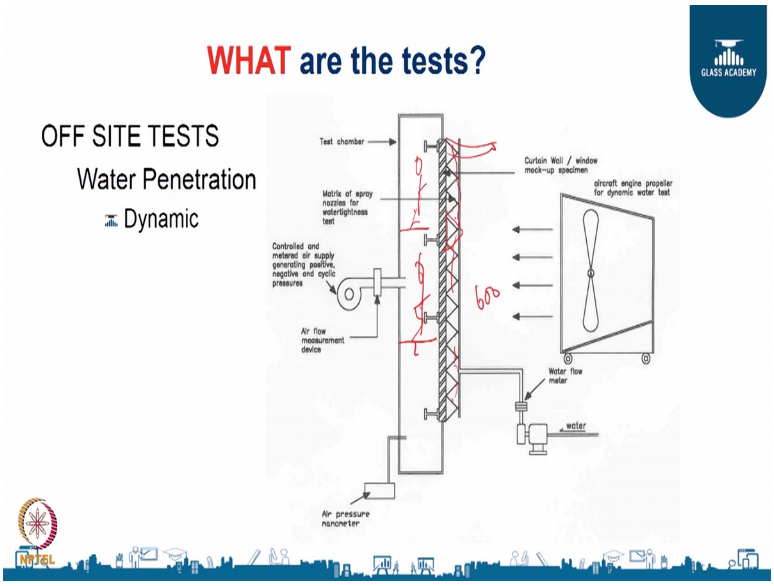
So, let us say the design of that particular facade is 2 kpa, then 15 percent of that 2 kpa is

300 Pascal's, and 30 percent is 600 Pascal's. So, the pressure is varied between 3, 3300 and 600 for 5 minutes and the cyclic pattern is between 3 and 5 seconds cyclical. This is like a replica of the real life situation, because generally wind does not blow on a continuous basis, it blows and stops and blows and stops. So, to create that kind of a real life situation, they have evolved this new the standard from the Australian standard; where you create the cyclical pattern and is very, very stringent.

So, the first 5 minutes is like 15 percent to 30 percent. Then the second 5 minutes you will have to go to 20 percent to 40 percent; which will be 400 to 800 Pascal's. And the third stage it will become 30 percent and to 60 percent is very, very high pressure, for a building and 600 to 1,200 Pascal's. So, again the cyclic will be between 600 Pascal's and 1,200 Pascal, it will keep varying for 5 minutes.

So, this if the facade passes; that means, that will in a real life situation it can absolutely not fail; provided the same methodologies followed the fabrication is done properly uninstalled properly. The system by itself is very very strong and it will not allow any water to pass through it.

(Refer Slide Time: 21:17)



There is the American standard AMA where they create a cyclonic pattern.

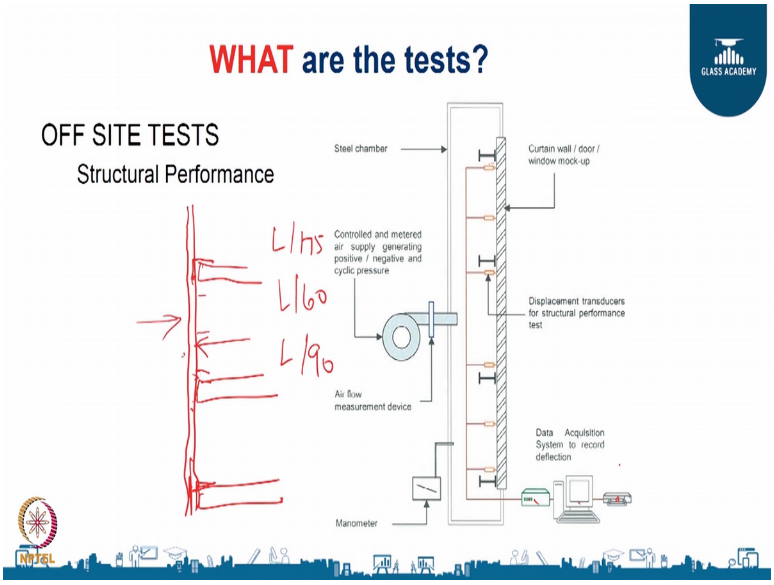
So, in order to create a cyclonic pattern, what they do is to add a huge kind of fan, and for that they recommend propeller engine which is one of this older engines which we see you know used in the Second World War. And these engines are being used today widely in all the performance testing labs to create that kind of cyclonic you know wind load on the facade. So, the water is being sprayed from outside. There will be people standing inside and observing here at these levels. And you have this propeller engine which is blowing the air, and you have the water which is continuously being sprayed for 15 minutes. And the door is opened there is no differential pressure inside. The blower is off the only pressure is from outside, normally this is 600 Pascal's. And 15 minutes the water is being sprayed and this is being blown air is being blown. So, you will have a kind of a water flowing from downwards into all the other directions.

So, there will be a video which I am attaching immediately after this, which will show how it looks in real life and the test is happening. And you will have a better idea when you see that video. So, this is for a 15-minute period, and after 15 minute it stop there should be ant water leak on the inside.

The dynamic also very ideal for any façade where you have some external features for example, you will have some pergola made of metal in which there will be glass. Or sometimes they will use a bullnose aluminium profile to give it a characteristic, some kind of a decorative thing which is ticking on the outside of the building. So, these are all external fixtures, and they want to know whether the hardware which has been used to hold those things are adequate.

So, when you create this kind of a cyclonic simulate this which atmospheric conditions, you can also know whether these are rattling or they are vibrating, or whether it is able to hold on despite the heavy wind pressure. So, this is the dynamic water penetration test.

(Refer Slide Time: 23:45)



So, after that we go to the structural performance test. Now structural performance test is to understand and ensure that the structure itself is able to hold because you have a large panel of glass, it gives a lot of resistance to the wind. And when you have a huge façade facing the wind, the impact of the wind on that entire building is pretty heavy. And so, the entire stress on the pressure is getting transferred onto the glass which is in turn getting transferred to the aluminium profiles; which are anchored on a floor to floor basis.

So, what happens is that there are deflections, the entire facade is giving in and coming back. And we need to measure how much it is coming in and coming out at a given wind load, and for which it is been designed. So, once that is checked and there are certain allowable deflection, because aluminium has the property of you know having some flexibility it can give in and then go back to it is a original position. But beyond a certain you know pressure it will deform permanently. So, the facade will start becoming you know concave or convex. So, that is not good, because structurally it starts to transfer the load into this next profile, and then there is a like a sequence of loads getting transferred and somewhere one of them will give way.

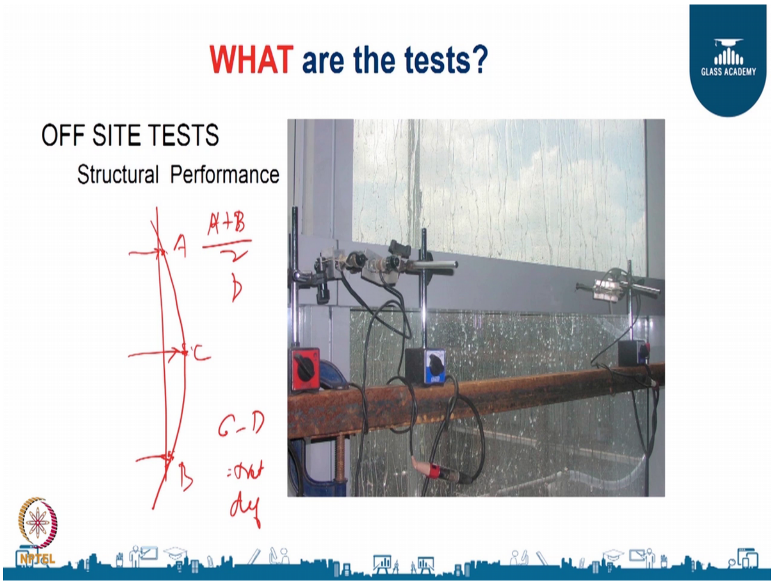
So, in order to avoid it we put it through the wind load. We simulate the wind loads and measure the deflections using transducers. So, for example, I just show you the cross section of a building where you have this facade. Now typically you have the slabs every floor with 3 meters or 4 meters, this is a slab. Now this facade is outside the slab, and this is fixed to the floor by a bracket.

So, what happens is, now there is a span from here to here which is free standing; from between the one bracket another bracket there is a thing. So, when you have pressure being come loading, here this is the aluminium frame and the glass is mounted on the aluminium frame.

So, we put transducers here and here. So, what happens is when you have positive pressure on the on the aluminium profile and the facade or negative pressure both ways, we measure how much it is moving out from 0 outwards or inwards. And there are allowables which is length by 175 in mm. That is the allowable for aluminium and L by 60 for single glass or L by 90 for double glaze glass. So, we have what is allowable and what is the actual, and the difference if the allowable is more than the actual; that means, it safe the facade is safe. If it is crossing it, then you have to go back and redesign and reinforce the aluminium or thickness of the glass, and then come back and retest and ensure that it is within the allowable, and thereafter allow go for the final mass production.

So, this entire transducers all the actual movement is being collected in a computer, and in a data acquisition system and there is a software which prints it out, and once the printer prints it we check it with the allowable. And if the allowable is if the actual is less than the allowable then it is a pass.

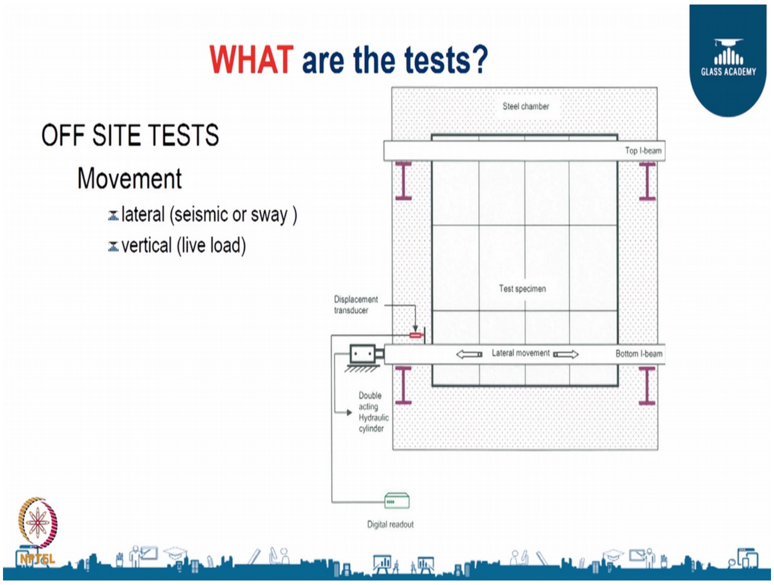
(Refer Slide Time: 27:31)



So, offsite the structural performance test is what I showed you. And this is a picture which shows the transducers which are mounted. Now you may ask why are they 3 transducers, actually there is a when there is a pressure it the whole thing is that the deflection is in a bow shape like this. So, because it is moving out what we need to know is the maximum is here, but there is certain amount of movement over here and here. So, we are having a transducer over here, a transducer over here and transducer over here.

So, let us say this is A, this is B and this is C. So, the allowable is the net deflection. So, we have to take A plus B divided by 2. And that figure let say is D C minus D is equal to net deflection. This net deflection should be less than be allowable. Then it is a pass, because sometimes this may be very big. It this may be bigger than the allowable, but when you directed from the average of this the net deflection should be less than the average.

(Refer Slide Time: 28:45)



The next one is the seismic movements; when you have a tall building high race building, there is a wind load acting on that building. There is a movement of the entire building, a entire movement the building is swaying, because of the wind loads. But we are not able to see it because it is very, very small. But then the since is this curtain wall may I show you showed you there, it is actually outside the slab, it is not fixed on the roof and the floor. It is outside the slab. And it is there are brackets outside the slab and the curtain wall aluminium frame is holding on bolts.

So, what happens is this when the building is swaying, these floor slabs are also moving. So, the movement of this floor slabs have to be accommodated by the curtain wall, it is a very rigid system, when there are movements in the slab the glass will shatter. So, in order to check whether the curtain wall has that ability to move along with the building and accommodate that movement we do a seismic movement test. So, this is either sideways you know which is the lateral movement, and sometimes you have the vertical live load movement also.

Typically modern buildings in order to reduce the quantum of unproductive area they cantilever the slab outside the column. So, you have casts slabs which are 1 and half or 2 meters which are outside the column. And then the curtain wall actually is installed at the end of the 2 meters. And thereafter when the building gets occupied they are adding the curtain wall is installed and then all the furnishing and the slabs and the flooring and the tiles everything is added on the cantilever. So, those act put some load on the slab and the slab tends to buckle a bit a few mm. So, the curtain wall should be able to accommodate that movement also.

So, we simulate this movement or this movement by using a hydraulic jack. So, once this movement is it is normally L by 500 that is roof to floor that height divided by 500 that will be the movement. Left side come back to 0 right side come back to 0 that is one cycle. So, this movement is done 3 times, and the pass fail criteria is just visual observation that should not be any glass falling off. They should not be any aluminium you know buckling or the hardware giving up. Visually, inspected they should not be any visual damage to this structure. So, that is the pass fail criteria for the seismic test.

(Refer Slide Time: 31:31)