Glass in buildings: Design and Application
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Lecture - 81
Case Studies for Building Envelop Design for Sustainable Building

Hello, I welcome you all for today's session Case Studies of Building Envelope Design for Sustainable Buildings.

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To introduce myself I am Akshay Gupta, I am an Architect with my Masters Degree in Environmental Design and Engineering. And I have been working in India and Abroad for the past 10 years and I am directing as a design consultants which is based out of Delhi. Today I will be covering three case studies primarily.

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All these three case studies are from Delhi NCR region and they are commercial buildings.

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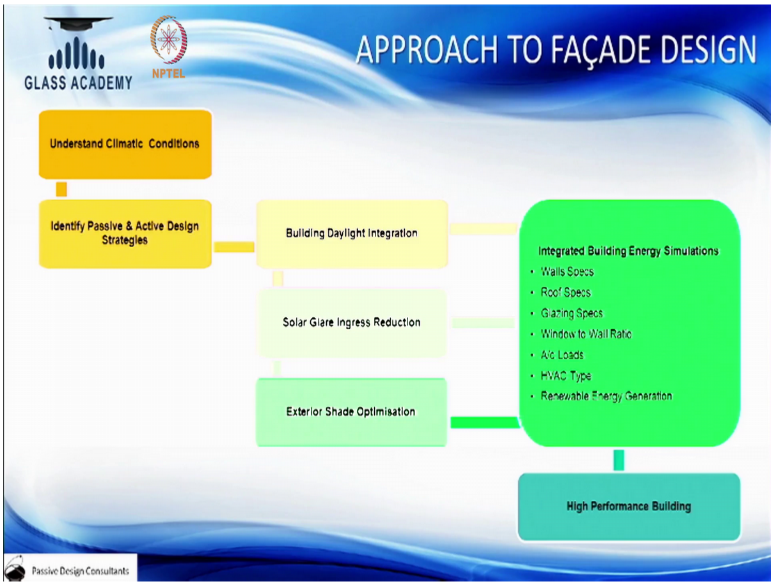

So, our topic is case studies on high performance building envelope, building envelope for sustainable building design, and to introduce you to our approach we generally take. We begin our studies with first our understanding with of the climate. Identify passive and active strategies suitable in that climate, going ahead with building daylight integration as we are talking about facade the facade basically has two main components;

walls and windows. So, the windows have to be optimized for multiple reasons; one is introduction of daylight in interiors of the building, second is views of the occupants from within the building to the outside, and third in this mode we do not want glare or we want minimal glare for the occupants within that building can be done comfortably. And in this regard we also want to make the building more energy efficient.

So, in order to conduct that we do integrate building daylight with solar glare ingress reduction in the building and exterior shade optimization; all these three happen along with integration of building energy simulations for the project. So, that we have an integrated design approach. We allow maximum or optimized daylight while preventing glare having well shade facades so that the building has minimal energy consumption and it performs well to deliver a high performance building.

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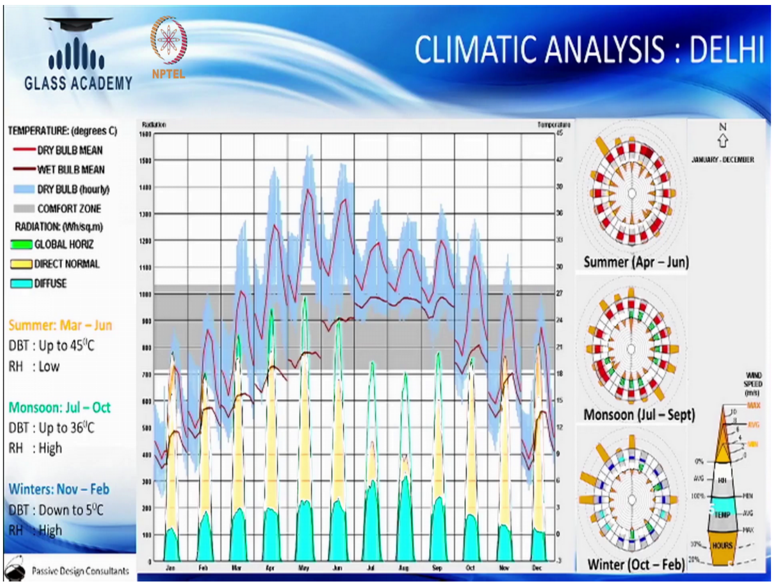

To begin with for these three case studies I will introduce you to the climate of Delhi; Delhi is primarily a composite climate we experience all different kind of climates like; extreme summer where the temperature goes almost up to 45 degrees, monsoon where it gets very humid and the temperature is generally up to 36 degrees, and very cold winters where the temperature drops down to almost 5 degree Celsius with higher relative humidity. Generally, in Delhi the wind is primarily from Northwest. However, during monsoon period we also get wind from Southeast.

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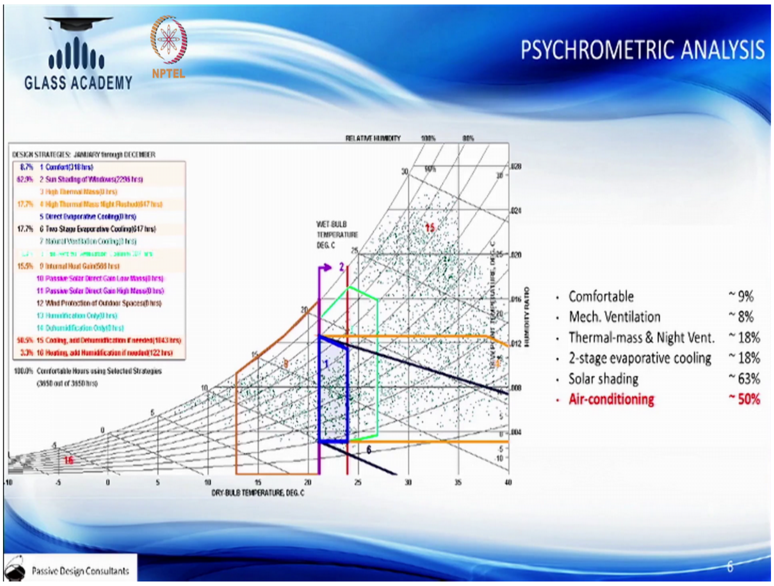

Looking at possible active and passive strategies we derive it through psychrometric analysis. Only approximately 9 percent period is thermally comfortable by the nature of the climate. For the remaining period we need certain interventions in building and primarily in building facade so that the buildings can be made energy efficient as well as comfortable for occupants.

So, the major strategies which have been identified for this kind of climate are solar shading which help you for almost 63 percent period or are applicable for approximately 63 percent period. Two stage evaporative cooling which also helps you for almost 18 percent period, thermal mass and night ventilation which is applicable for 18 percent period; mechanical ventilation further enhances thermal comfort for a approximately 8 percent period. And for the remaining approximately 50 percent period we do need air conditioning specifically for commercial buildings to make occupants in those buildings comfortable.

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To begin with: the 1st case study this case study is a commercial building which is the core and shell which means that the client was only interested in making the building facade in the core of the building, remaining things will not be developed or provided by him in the building. A tenant will come and will occupy the space and will install the remaining items.

The building is designed or is aspiring platinum IGBC green new building rating system the building is approximately 17000 square meter in area total built up area and has ground plus 7 floors with one basement. On your left use of the slide you see the image which is rendered for after the proposal that we have given to our client to the architect and we will show you how we have arrived at this particular facade.

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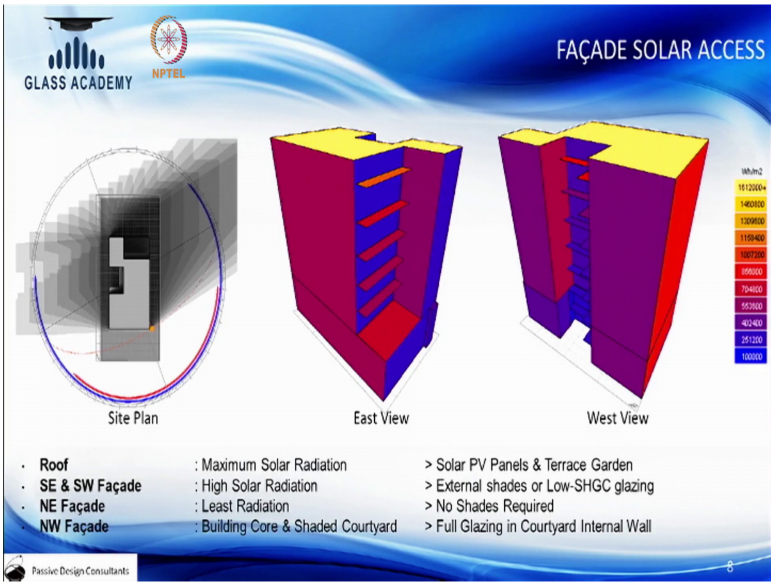

To begin we started the project with the building shape mass which was given to us by the client, by the architect, the building is primarily diagonally oriented on your left you would see in this slide this is showing a site plan, where the light grey colour is for the building mass. The building is basically open on three sides Southwest, Southeast and Northeast. These are the three main building facades we did a facade solar access analysis for the project and we realized that the Northeast facade because of some of the existing shades which were already designed by the architect was very well shaded. Also being Northeast the radiations we were getting on the north east facade were very minimal; while the southeast and the southwest facades were primarily two main exposed surfaces of the building envelope which were receiving very high solar radiation.

So, from the facade solar analysis or access analysis what we realized was that the roof was actually receiving the maximum solar radiation. So, one would go for solar PV installation or terrace gardens or Southeast and Southwest facades we do need external shading devices and or glazing which has low solar heat gain coefficient. On the north east facade since it had least radiation as such no shades are required which were originally designed by the architect. So, these perhaps can be removed if required. On the Northwest facade the building was basically facing the adjacent plot and the adjacent building. So, primarily it was blank, but there is a courtyard which is facing that direction in the project and that particular facade since that courtyard which is shaded could have full glazing.

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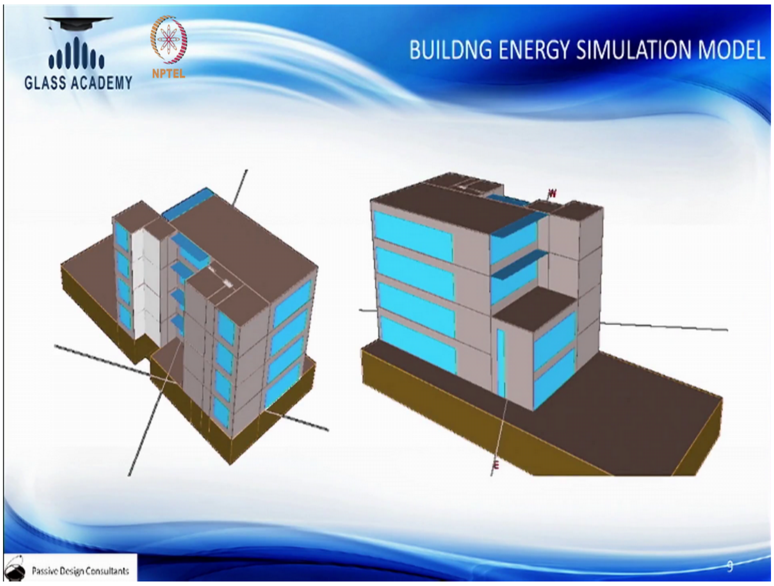

Moving on we developed energy building model particular project. These are the images on the slides which show the model was made how it was made. The particular building geometry and the glazing, you will see that project has significant glazing area.

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GLASS ACADEMY NPTEL

BUILDNG ENERGY SIMULATION MODEL

S.No.	Description	ASHRAE 90.1-2010 Baseline	Design Case
1	Exterior Walls (Btu/hr Sqft F)	0.124	0.12 (AAC – 8")
2	Roof	0.063	0.065 (Over-deck 3" XPS)
3	Glazing	U-Value: 1.2 SHGC : 0.25	U-Value: 1 SHGC : 0.8 6mm Clear Glazing
4	Lighting Power Density (W/Sqft)	Building: 0.9 Parking: 0.25	Building: 0.9 Parking: 0.25
5	Equipment Power Density (W/Sqft)	Office Areas: 2.5	Office Areas: 2.5
6	HVAC Type	Water Cooled Screw Chiller COP: 4.5	VRV System COP: 3.4
7	Fresh Air Supply	5 cfm/ Person + 0.06 cfm/Sqft	5 cfm/ Person + 0.06 cfm/Sqft
8	Occupancy Schedule	9AM – 7PM Monday - Saturday	9AM – 7PM Monday - Saturday

Passive Design Consultants

It was calculated that the building had approximately 38 percent window to wall ratio. The window to wall ratio that we observed originally designed was in line with ECBC requirement, and it was less than 40 percent. So, there was not much that we have suggested on the window to wall ratios. However, optimization of the fenestrations was more critical and that has been focused on and that is what I will be discussing with you.

When we started with the energy simulation we basically laid down the ASHRAE 90.1 baseline requirements and compared those with a typical design case. A design case which was already designed or proposed by the architect and then we went ahead to see what we can further optimize here; for the cost optimization and for a better higher performance of the building.

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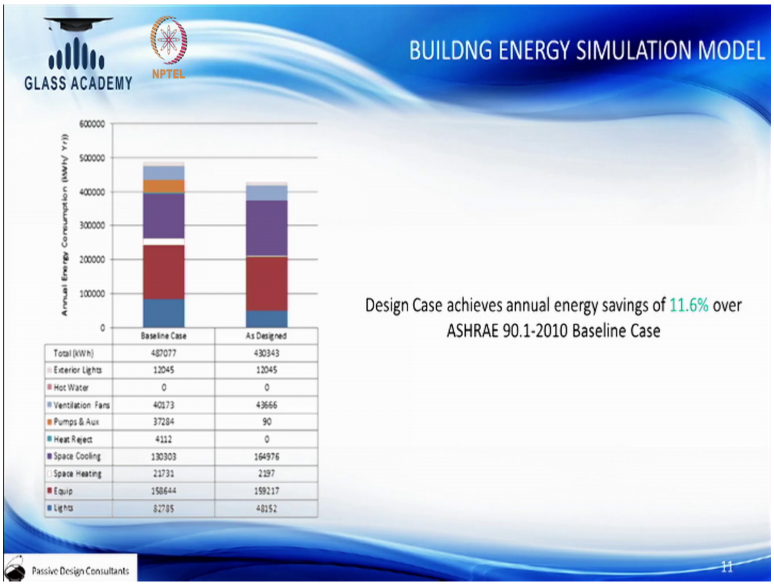

Upon simulation the building shows that the design case as proposed by the architect was already saving 11 and half percent energy as compared to ASHRAE 90.1 baseline case.

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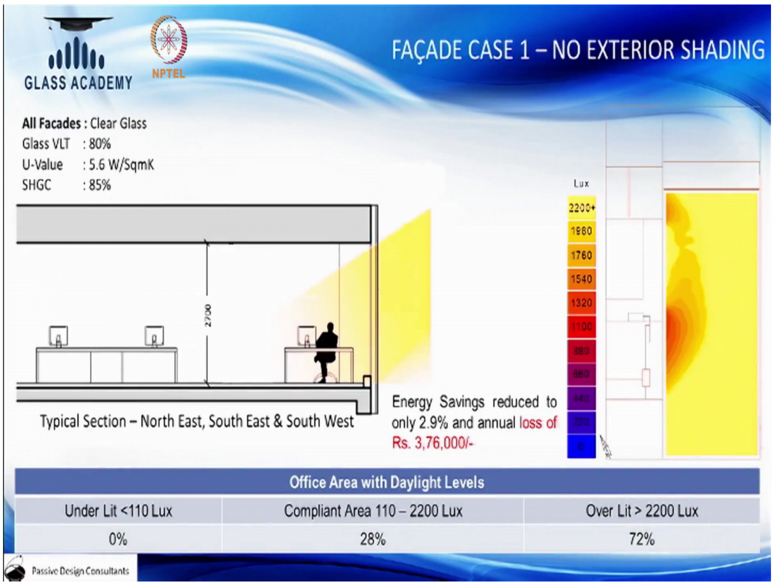

So, we started the building while considering what if the building facade is absolutely clear where we are using clear glass; the glass VLT we considered for the facade was 80 percent the facade did not have any exterior shading devices on Southeast and Southwest facades which are the more critical facades here in the project. The glass U value was 5.6 watt per square meter Kelvin which is which is for a clear single glass 6 mm clear glass.

We realized that with this kind of a configuration, we are achieving almost only 28 percent daylight areas in the regularly occupied building plan. On our right in the slide we see this is typical building plan; building flow plan that we had. The yellow highlighted area is the office area which will be leased out. On your left the spaces that we see here are the core spaces like fire escapes staircase, pantry, toilets and the left lobby

So, we were analyzing daylight majorly in the regularly occupied space which is the office area. As you can see through daylight simulation we realized that there were 72 percent overlaid spaces or area which is receiving more than required daylight which is defined to be 2200 Lux by IGBC that is what we have considered. More than 72 percent of the floor plan was receiving more than 2200 Lux which is over lit. And this will greatly cause glare as a problem.

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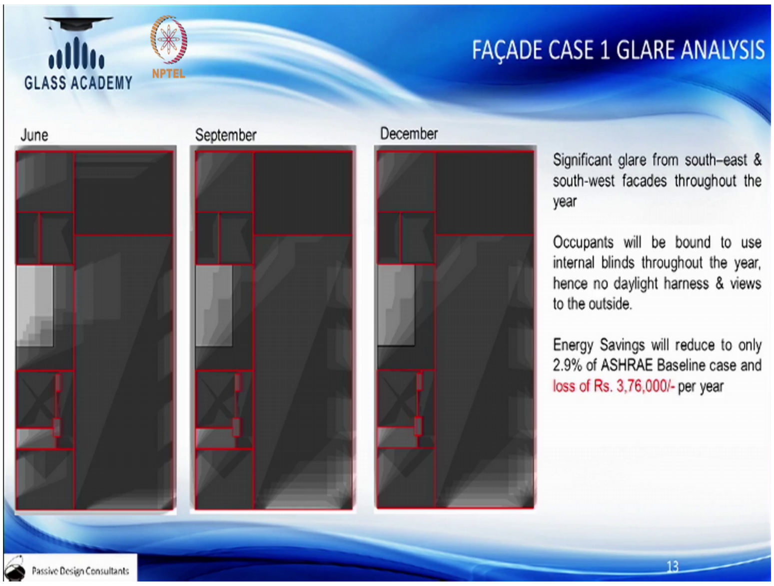

This slide is focusing on the direct solar ingress; direct solar radiation ingress within the building.

We see primarily on summer solicitous equinox and on winter solicitous on all these 3 typical days which kind of represent the entire year. The glare was significant from both Southeast and the Southwest direction in the office space. And this would basically lead to the occupants of the building to use more internal blinds, using more internal blinds will primarily negate the use or the purpose of having windows. Because, as soon as we have the internal blinds there would not be any daylight which is coming through those; in inside of the building occupants will not get used to the outside and we will completely rely on artificial lighting.

So, even though the project plan or the architectural plan has a good potential to be 100 percent daylight because of the glare, we will not be able to use that daylight purposeful daylight. And primarily through energy simulations we have analyzed that the project energy savings which was originally observed to be 11.6 percent savings will reduce down to only 2.9 percent and this will equate to almost 376000 rupees of monetary loss to the building occupants for the entire building.

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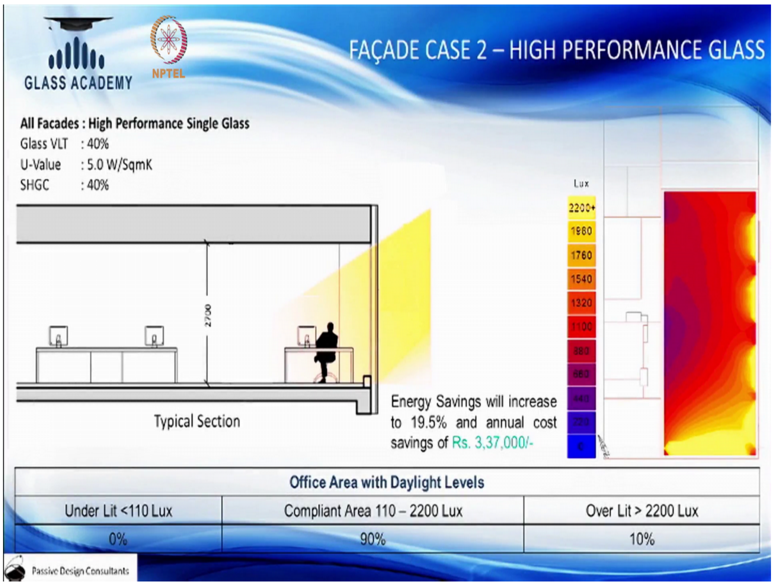

So, what is the first approach? Typically the first approach is that we go with the single high performance glass: a glass which has relatively lower VLT which reduces the solar heat gain coefficient which has a lower SHGC and reduces the solar heat gain inside the building as well. So, we selected this glass which has 40 percent VLT and VLT is visual light transmittance the amount of light that can pass through the glass. And the solar region coefficient was observed or was selected to be of around 40 percent, U value of 5 which is slightly lower than the single clear glass, but not significantly lower.

With this we observed that the energy savings in the project which would increased to 19.5 percent from 11.6 originally, and the annual cost savings will also be increased by 337000 rupees annually. Further, on the daylight front we observed that although the floor is now 90 percent well daylight. However, still on Northeast, Southeast and Southwest facades because there is no external shading device and as a consequence these people will have a tendency to still again use internal blinds and which will not be very helpful.

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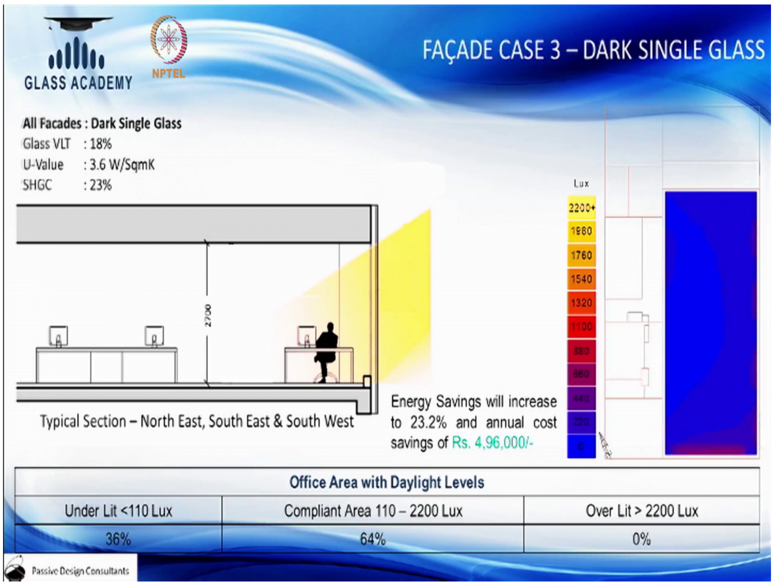

So, this we did not settle for this facade strategy. We moved ahead we tried the next stage which is when we have absolutely dark glass used in the facades to prevent glare problem for the people who are sitting next to the window. In that regard we selected a glass which had 18 percent VLT as a consequence the SHGC is also reduced to 23 percent which is good for the energy efficiency of the project for reducing thermal heat solar heat gains. While the U value also reduced down to 3.6 watt per square meter degree Kelvin, almost half of what single clear glass would offer. This increased this change on the building facades improved our energy savings from 19.2 percent in the previous slide to 23 percent and the cost savings to 496000 almost 500000 rupees.

However, on the daylight ingress part, on the daylight front we realized that only 64 of the spaces which actually be well day lit while almost 36 percent areas will be under lit. Under lit are the areas which receive less than 110 Lux as recommended by IGBC; anything any area receiving less than 110 Lux is not receiving adequate daylight and one would need additional artificial lighting to perform a task comfortably.

However, in this case the over lit areas or the areas which were receiving direct glare were minimized to0 percent. So, they were there is 0 glare, but we could not settle for this as the daylight ingress the quality of daylight in the interiors was not very good.

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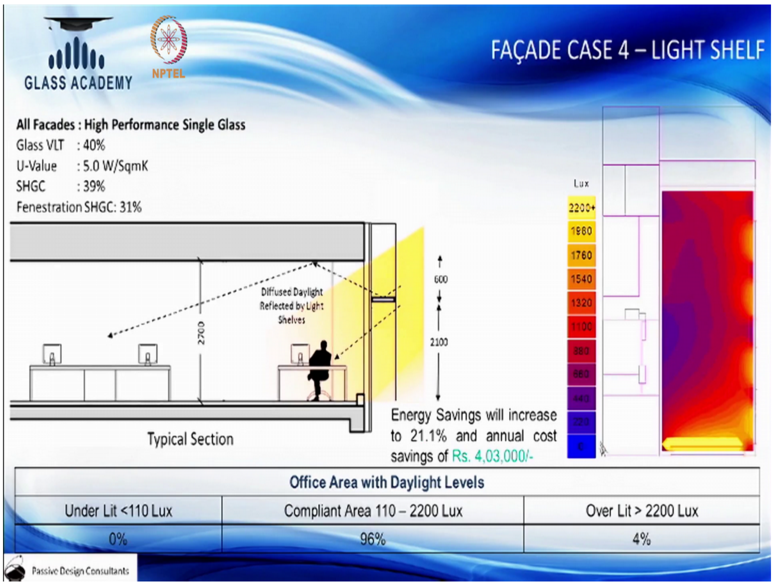

We moved on to case four where we introduced 1 light shelf on the Southeast and Southwest facades. The light shelf was 600 mm deep and 7 feet or approximately 2100 mm from the internal finish flow level. With this we went ahead with the high performance single glass, not DGU. With this case the glass was having VLT of 40 percent and solar heat gain coefficient of 39 percent.

However, because we have used the exterior light shelf which was 600 mm deep we were able to effectively reduce fenestration SHGC to 31 percent as the shading device as the light shelf is also acting as a shading device and ultimately reducing certain amount of solar heat gain as well

What we observed with these results was that the compliant area; area receiving good quality daylight was increased to 96 percent of the floor area was receiving between 110 Lux to 2200 Lux. Under lit areas receiving less than 110 Lux in this case were reduced to 0. So, there are no under lit areas in the regularly occupied areas in the office. And however, we saw that on the Western facade we still have approximately 4 percent area which was getting more than 2200 Lux and this was found to be that direct glare. This direct glare which, we got a hint from daylight simulation was confirmed or validated through the glare ingress analysis as shown in this slide and we can see that equinox to December or winter solicitous there a significant glare observed from the Southwest facade.

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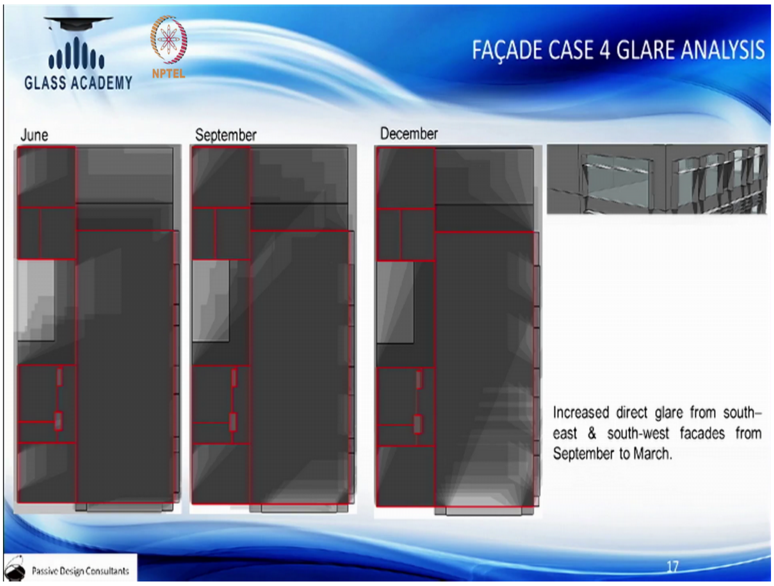

So, they should be prevented in order to have a best or most optimally designed building facade.

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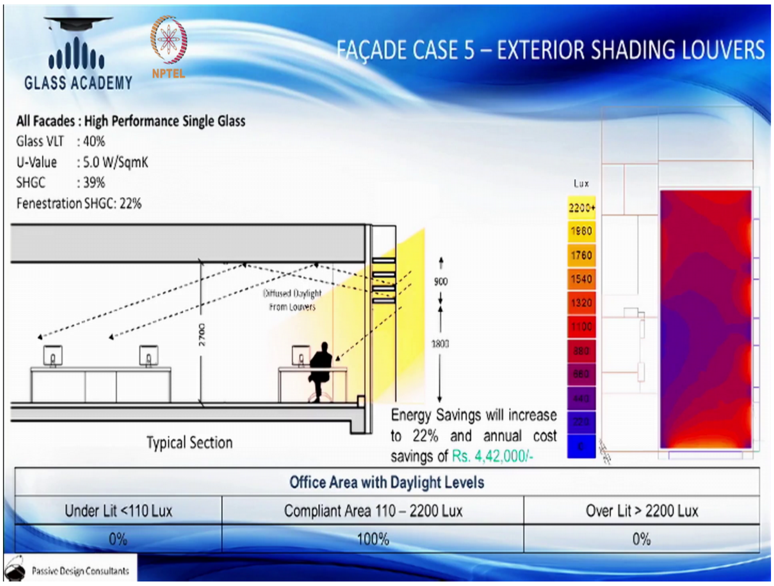

Further, we developed another case a case where we had more louvers working as external shading devices as well as light shells. However, we will call them exterior shading louvers with these the overall impact was that the fenestration SHGC was reduced down to 22 percent, only 22 percent of solar heat will be allowed to pass through the facade. This rather reduced our energy savings to 22 percent as compared to the previous case where it was dark glass and the savings were slightly above 24 percent.

However, the annual cost savings were still reasonable 442000 annually. The good part in this design was that we had 0 under lit areas in the project and 0 over lit areas in the project. So, there was no chance of glare, and while still getting 100 percent well daylight areas.

The client had a apprehension that with so many louvers and the facade this will lead to a very high maintenance of the facade, because of the environment that we have in Delhi; dust accumulation on these louvers and other environmental related stuff.

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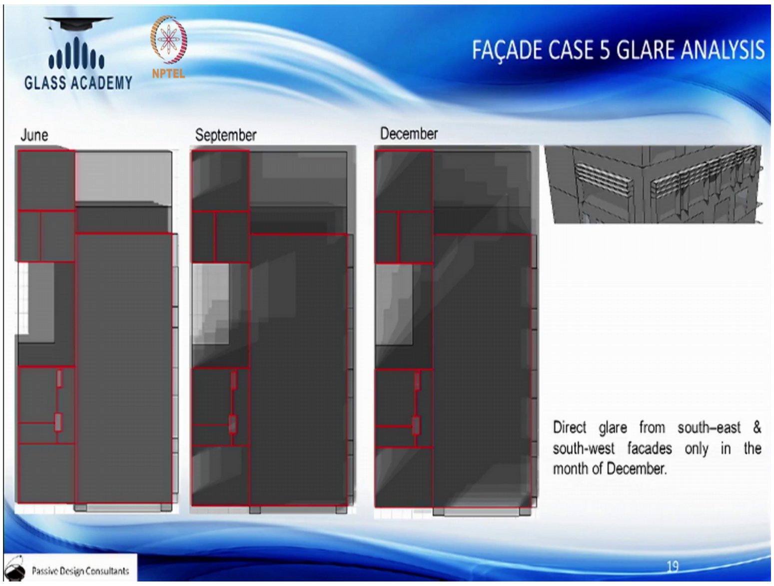

Validated here in this project through the glare analysis; we saw that there is little glare only which is available in the December month or during winter season. However, we do know understand that for Delhi during this period the outside atmosphere or the outside conditions are largely foggy, because of which we do not receive too much direct solar radiation. And if there is any direct solar radiation it is generally welcome in the building as people or occupants do enjoy it.

So, we can still withhold or we can with we can still have that external solar direct ingress and the months of December and January or in the winter months. While for the remaining large part of the year the space was glare free from Southeast and Southwest facades.

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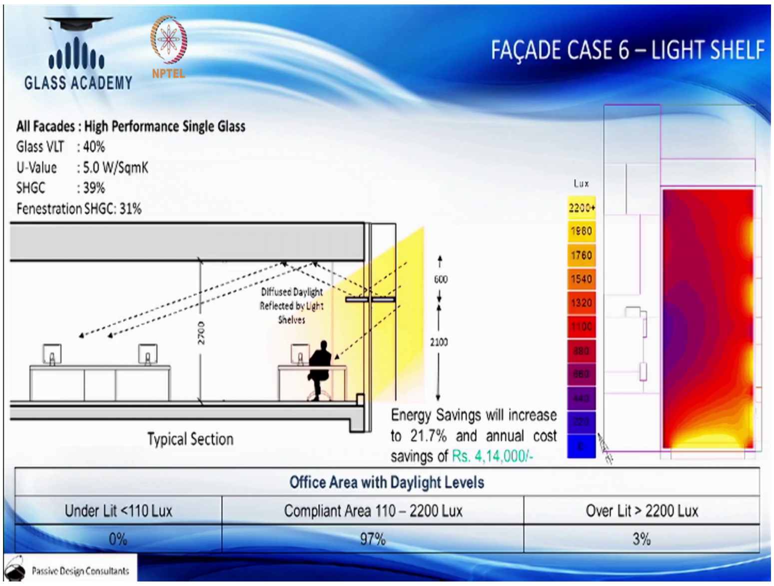

As, I have mentioned to you that in the previous case the client was still concerned about having too much maintenance of the facade. So, we developed another system where we had double light shelves: one outside the building facade and one inside. So, that maintenance is minimal as the internal light shelf would not really require as much maintenance.

The internal light shelf however helped us in minimizing the glare for the building occupants and also improve the quality of the daylight. What we realized was that now the purposeful daylight between 110 Lux to 2200 Lux was received in almost 97 percent of the period. While there is still some glare which is there in 3 percent area. The energy savings were dropped down to 21.7 percent for the very simple reason that the internal light shelf will not help in reducing the solar heat gain and it will only help in the better distribution of daylight, but not on the preventing external solar heat gain inside the building.

As a replication we suggested that the client now can have internal blinds which can be used only during the time of the day when the glare is there and that will be removed when the glare factor is not there.

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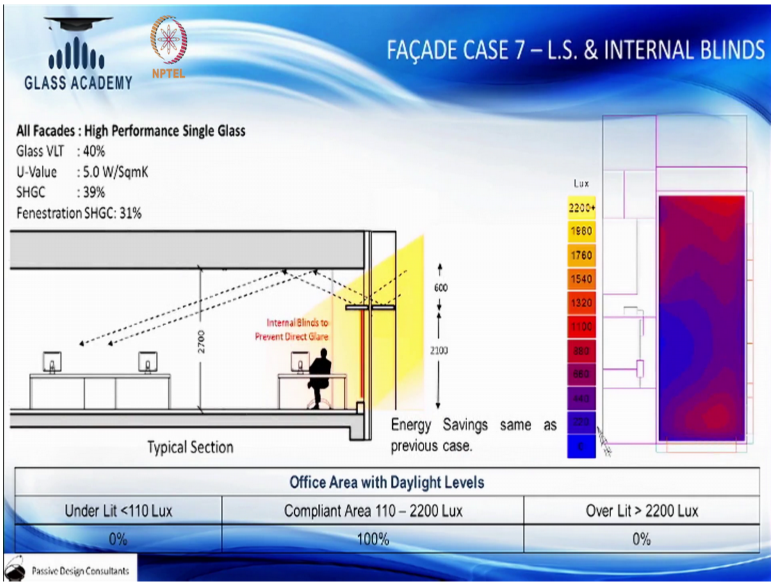

However, even if we consider a worst case that all the time the internal blinds are still kept. Because of the light shelves we were still able to achieve good daylight within the space well uniform daylight and we were able to achieve 100 percent area having daylight with 0 glare and 0 under lit areas.

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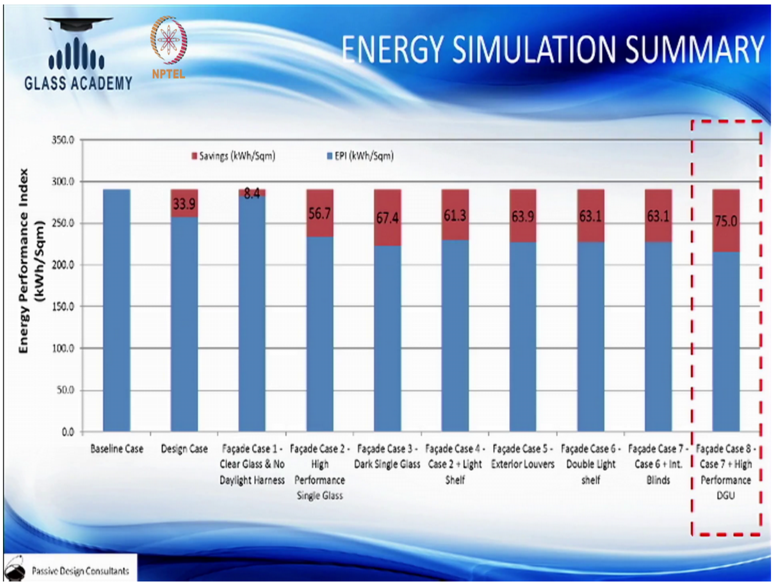

As a summary when we did energy simulation of all these cases till case seven which was the last one. We realized that we would the project could save almost up to 63.1 kilowatt hour per square meter of energy, and if that case was only with the single high performance glass. However, for this particular project if the glass was changed to high performance DGU: double glazing unit we could save our energy from 63.1 kilowatt hour per square meter to 75 kilowatt hour per square meter annually. And that was ultimately final design which the client like and we went ahead with that.