Glass in Buildings: Design and Application
Mr. Ashish K Jain
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 79
Building Envelope Design for Sustainable Buildings

Hello friends, this lecture is about Building Envelope Design for Sustainable Buildings. Is a very interesting topic and a very important topic in today's context where the buildings are not only facing the challenge of being benchmark globally about the way they look and the how and they feel. But, also equally important the way they perform. Building envelope for any building is a first phase which actually faces all the issues of climate of the environment and makes it more comfortable and more viable for the people to really operate the building from inside. So, let us go through this interesting topic about the building envelop.

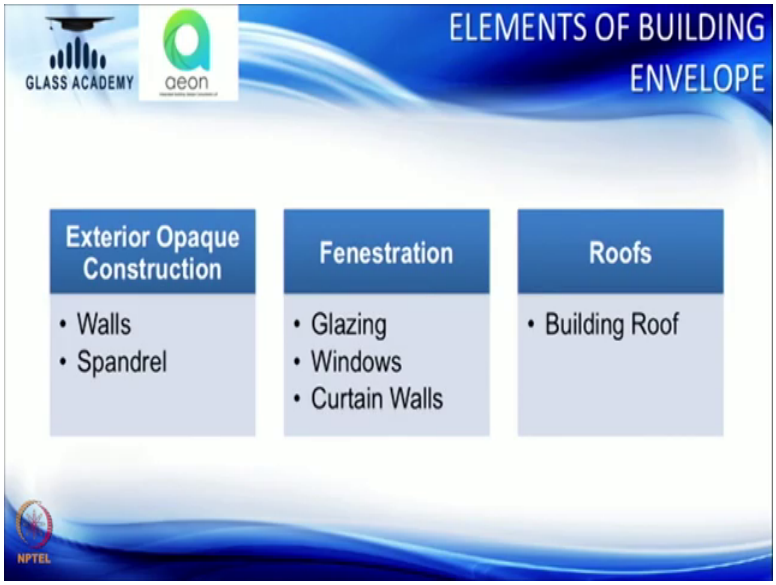
(Refer Slide Time: 01:18)

As I said these are the main issues which are to be dealt with when we are talking about building envelope for any particular building. The opportunity in a country like India where sun is available for 300 days, but when sun is there it definitely bring in the daylight with daylight the problem of heat glare also comes.

So, it become important that all of these elements are looked in a holistic manner whenever we are designing any building envelope. So, what is required is to achieve a

right balance to achieve visual comfort, thermal comfort, occupant health and the energy efficiency. Gone are the days that we only deal with the energy efficiency part of a building. Today we are talking of the wellbeing the comfort, the health aspect of occupants living inside the building. So, it becomes more and more important how do we tackle all these issues together.

(Refer Slide Time: 02:16)



A building envelop is basically form with elements which are captured here. One of the first is the opaque exterior construction which means the walls that we see outside any building. Fenestration, which is the glazing part in the form of either a window or a curtain wall or a structural glazing and the building roof, the topmost part of any building. Each one of these elements have got its own importance the kind of materials we use, the kind of design we do for any one of them actually defines the performance of a building in a different manner.

(Refer Slide Time: 02:56)

The right approach of design for a building envelop starts right from understanding the climate better. Understanding the climate is as important as taking the first step to anything. You can see a lot of old buildings, monuments, the building which have been constructed 100's of years ago, they are still standing tall mainly because they respond to climate of that particular area.

The building was designed in a manner that they are comfortable even today, they do not really need any electricity and the credit goes to the climate responsiveness and the kind of materials which are used in those so, it is important element. After that whenever the building is getting started to design the first thing is the floor plate, how much deep should a floor plate be and a very deep floor plate with only exterior glazing may not really give you the desired outcomes on the daylight front. Narrower building may also not fit best. So, an optimum floor depth is required when we start designing that.

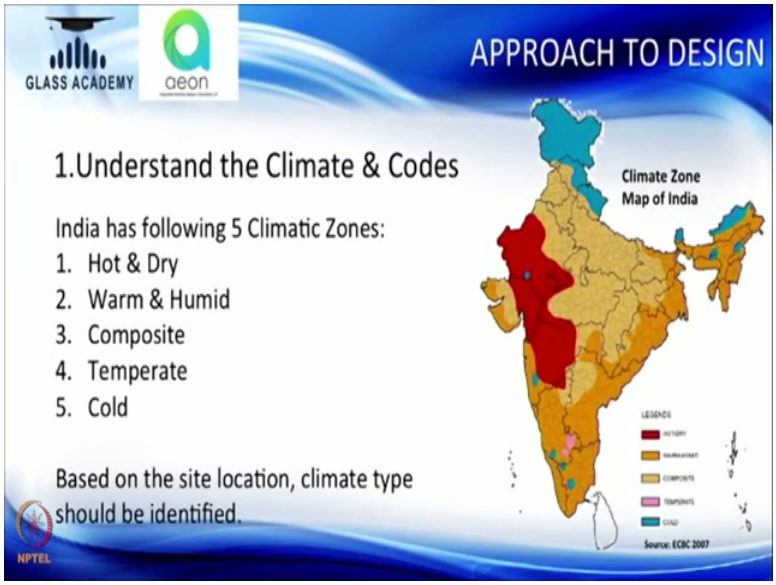
Optimising the window to wall ratio is the next important step for any facade when we talk about the kind of materials we are going to use there; the first thing is how much of the glazing, how much of the wall area should be there. So, window to wall ratio defining it, optimising it is very important because, too less WWR means very less glazed areas which would not be good daylight. Excess of glazed areas means higher WWR will penalise you on the heat ingress, the energy cost of the building, the over size of the systems, more capital cost and more operational cost, if the materials are not

selected properly. So, an optimisation is required whenever we are talking about how much would be the glazing area, how much would be the solid area.

Facade shading so, after you have designed whatever amount of glazing how best is that shaded. Now, in our country where a lot of heat is there outside we have to deal with the proper shading to shade the facades and to keep the heat out. So, facade shading is the next step.

Controlling glare and enhancing daylight that is combination which is very important when we discuss about the ingress of light with that the ingress of heat and the glare. So, all these 3 elements of controlling glare enhanced daylight and control heat transfer is something which has to be taken whole strictly. I will show you in one of the case studies that I have how to do that. And specify building envelop properties according to that. So, where to start? The first step is to start with the basics.

(Refer Slide Time: 06:17)

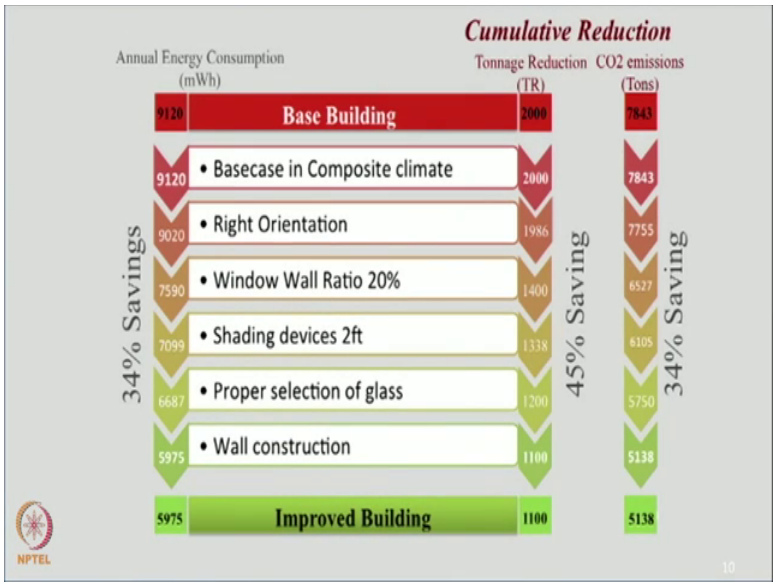


As I said understanding the climate here you see the climatic zone map of India. India has got 5 climatic zone hot and dry warm and humid, composite, temperate and cold. Now, each of the climates has got it is own parameters it is own climatic parameters which are important to be understood and building design has to come across according to that.

So, when we talk about the climate and the design of the building, one important element

is to combine passive with active because, it is the passive measures which actually enable you to reduce the cost of the building at the basic level itself. If the passive measures are done right a lot of optimisation happens there, no cost solutions are achieved and you really get the desired output with a lesser capital investment.

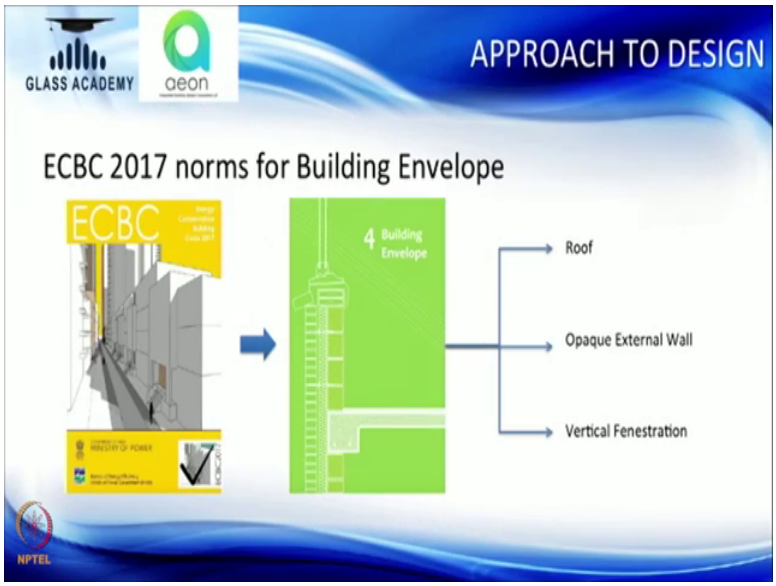
(Refer Slide Time: 07:11)



Just you give you a brief on that, this is the kind of potential which is there if we do the basic principles right, if we incorporate the passive strategies right and if we do the selection of materials right. Around 30 to 40 percent savings can be achieved on the energy front if we do the basic thing right, which means the right orientation of the building, right window to wall ratio, shading devices, proper selection of glass and wall construction.

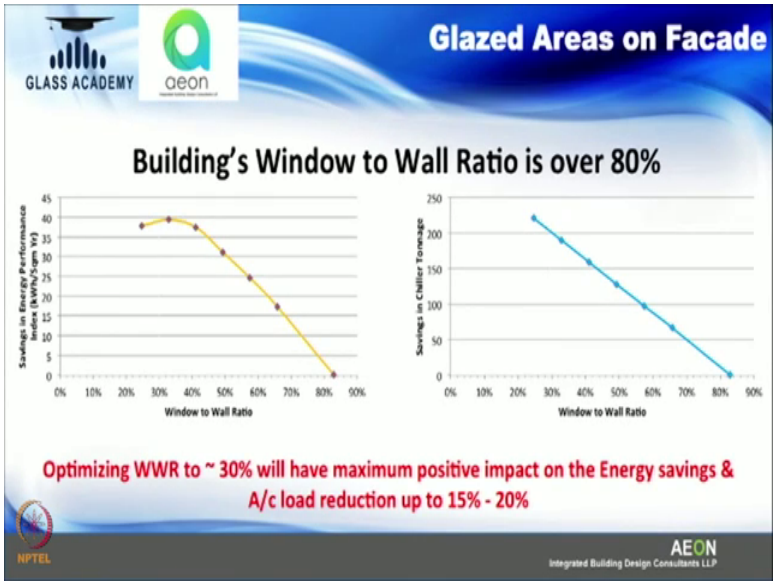
When you are increasing the savings there is also potential that you reduce your air conditioning size. While your energy consumption is linked with your operational cost, reduction in tonnage becomes your capital costs savings. And in the whole process you reduce the CO 2 emissions, which is the most important environmental parameter of any building design. Buildings are responsible for around 40 percent of CO 2 emissions globally. And if we deal with our designs properly, we designed the buildings properly there is a huge contribution that the building sector can make one reducing the global emissions in terms of the CO 2.

(Refer Slide Time: 08:33)



In India we also have got the energy conservation building code. Now, ECBC 2017 provides the norms for building envelop also. In many states it is becoming mandatory now to follow ECBC and implement in the project. And the requirements that are supposed to be achieved for different elements of the building envelop including roof, walls, fenestration all of that is laid out there. It is important in the process to really refer to it and avoid by it. What this ECBC 2017 is also doing is providing some guidelines on how to really get into the building envelop design which comes as very handy for many people. So, it is definitely a good step to you know refer.

(Refer Slide Time: 09:29)

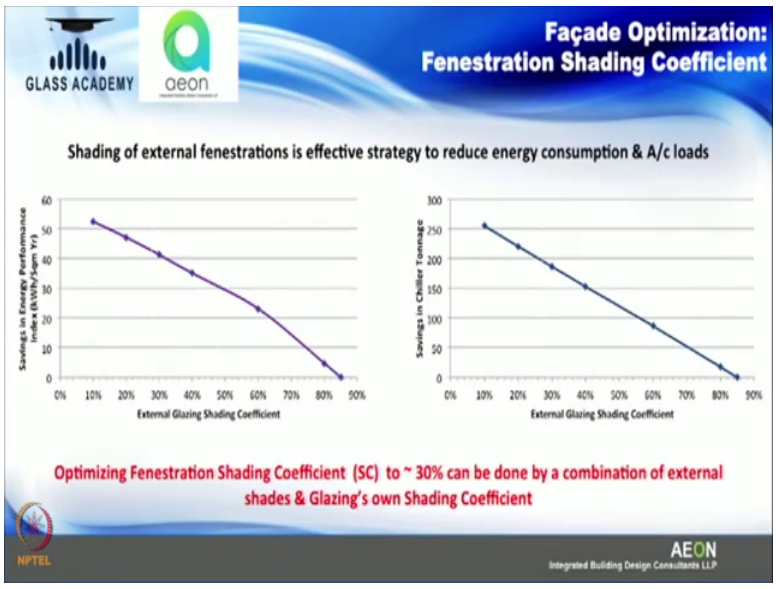


Now, I will take you to the case study which is for an office building, it is an office building located in NCR. Now, as I said you know the buildings with more and more emphasis on the aesthetics of the building we intend to go with more glass, going with more glass is not a problem, but optimising it to the best possible manner is something which is required. In this particular case in the building's design started with the window to wall ratio of 80 percent.

Now, this analysis was done actually at the right concept stage to analyse what happens if we change this WWR from 80 percent to something else or what should be that optimum WWR that we should be achieving in a design to make it a high performance building. Now, it is a very important step and also very motivating right at the concept stage because that is where you end up doing the best design if your window to wall ratios are optimised at that level it is something which you can enjoy throughout the project.

In this case particularly what we did was the analysis are done for seeing really how much effect of changing the WWR happens on the energy front energy consumption of a building and how much impact of that comes on the AC sizing of the building. With this analysis we found that the WWR of 30 percent is going to give the best you know effect in terms of energy savings and also AC loads can be reduced by around 15 to 20 percent.

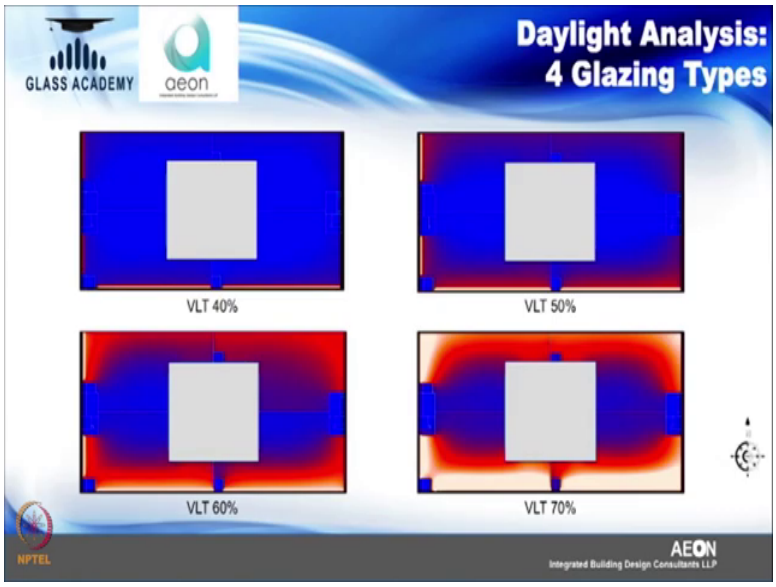
(Refer Slide Time: 11:26)



This analysis is about fenestrations shading coefficient how much shading coefficient

should be go for. Again the similar analysis on energy and chiller tonnage and what was identified that a shading coefficient of 30 percent can be a good shading coefficient to look at in terms of optimising the building performance.

(Refer Slide Time: 11:48)

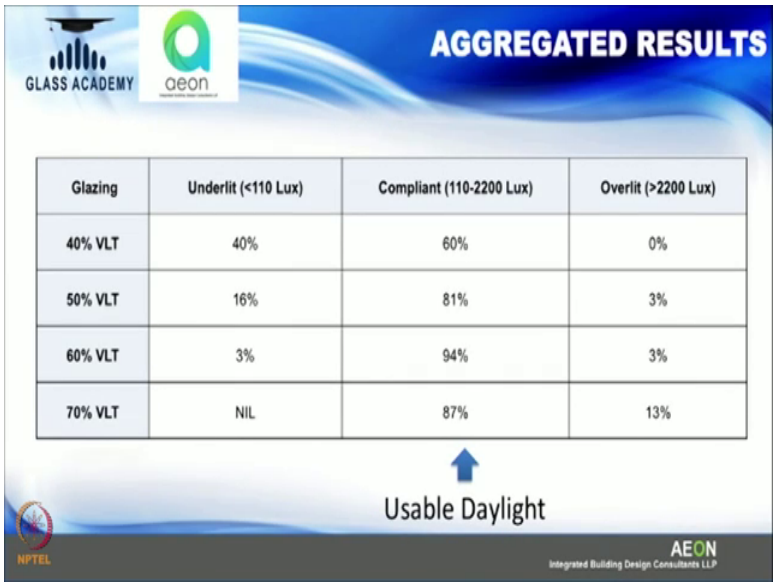


Then we did the daylight analysis to identify how much effect of different WWR is going to be there on the daylight harness in the building. And daylight to me it is very important because with the best utilisation of daylight we can reduce our lighting consumption which is a win in every sense. And daylight has been you know there are there has been many studies which have proved that daylight is something which has got a lot of positive impacts on the people health their comfort.

So, if in a place you are able to utilise daylight in a best possible manner it is solving all the purposes of efficiency health and comfort. So, that is an important area to look at. In this case we looked at how much daylight do we achieve if you know the WWR was kept at the design case and the kind of glazing we select. So, visible light transmittance of 40 percent which is the property of a glass if we choose that how much is going to be the daylight.

If I increase my VLT by 10 percent at 50 percent how will it perform at 60 percent VLT and at 70 percent VLT? So, different you can actually choose the glazing type based on there the analysis rather than the guesstimates.

(Refer Slide Time: 13:19)

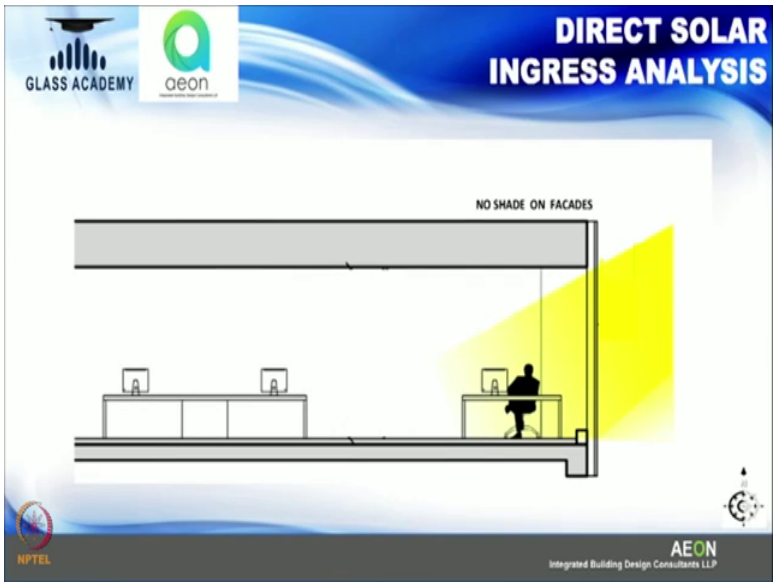


In this case what we found was that you will see these 3 columns here which defines underlit areas, compliant areas and overlit areas. Now, this is that zone which is more like a useable daylight. If you have lesser Lux level then what is required? The areas going to be dark, we are going to switch on the light. If you have overlit phases means you have got more daylight than what you need your probably going to use blinds to get that daylight out. And again you are going to use your artificial lights.

In many cases we have seen this as a problem, glazing are designed without really looking at the overlit spaces or the glare aspect and we end up you know seeing situations where even if there is a glazing we are not able to use the daylight.

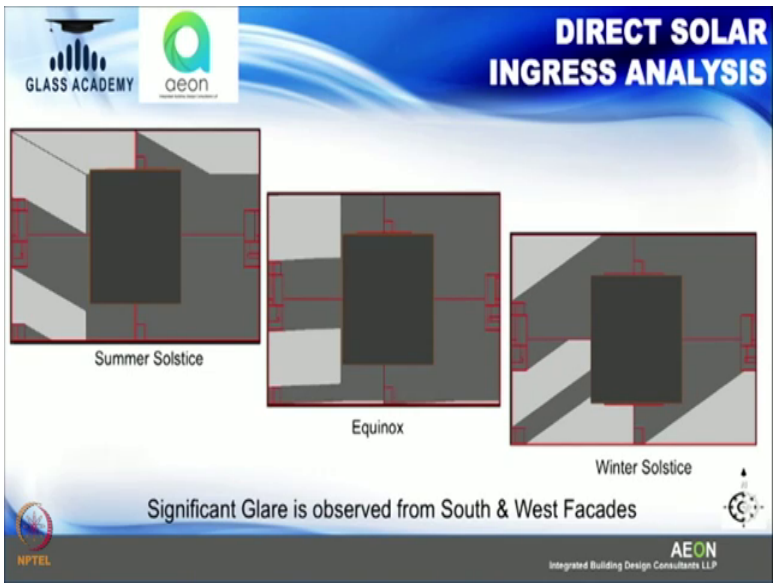
So, usable daylight is something which is what we are looking at. In these 4 cases the useable daylight areas were coming out to be 60 percent, 81, 94 percent and 87 percent. Now, the target we were setting for ourselves in this particular case was around 90 percent. So, that is something we get with 60 percent VLT and 70 percent VLT and this was something which is more closer to our target impact better than the target. So, we can go this glass.

(Refer Slide Time: 14:47)



But, after that we also studied how much is my direct solar ingress going to come with the kind of glazing I have, If I have no shades.

(Refer Slide Time: 14:55)



This is the glare analysis where all the white patches that we see our glare. Is done for 3 different seasons summer, equinox and winter solstice. And what we found with the solar ingress analysis was that there is a acute glare which comes from South and West facades.

So, if people are really sitting over there they might not be comfortable they may be

using blinds and the whole concept of you know the high performance building may go off. So, there has to be glare mitigation it is need to be adopted.

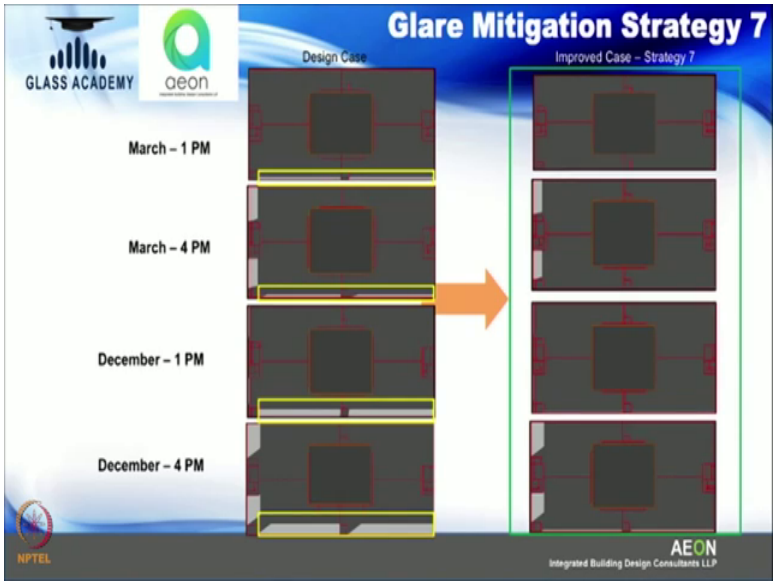
(Refer Slide Time: 15:40)

Then we also did we also took a deep dive to understand how much is the problem for how long is the problem in terms of glare to design the building in accordance with that. And from the South facade what was identified? For all 12 months we identified the glare timings and what was good to see was that from May to August there was actually no glare that was observed. But, there was a lot of glare on in the other months. So, there is about 8 to 9 hours where we were facing the problem of glare.

(Refer Slide Time: 16:29)

Then we started developing the options what could be the you know glare mitigation strategies and we worked out there are you know 7 options in this case of different types where we have got horizontal overhangs of different sizes of a different numbers, spacing between them, angular ones and different combinations were worked out.

(Refer Slide Time: 16:58)



And for each one of that we really analyses how much effect we get. So, with first strategy the results were you know ok, but not very significant. Then we started analysing the other ones and results kept improving and we could actually eliminate the

glare during entire summer and mid seasons with the strategies, only for the you know winter season there was slight layer which was left because of the lower sun angles.

(Refer Slide Time: 17:38)

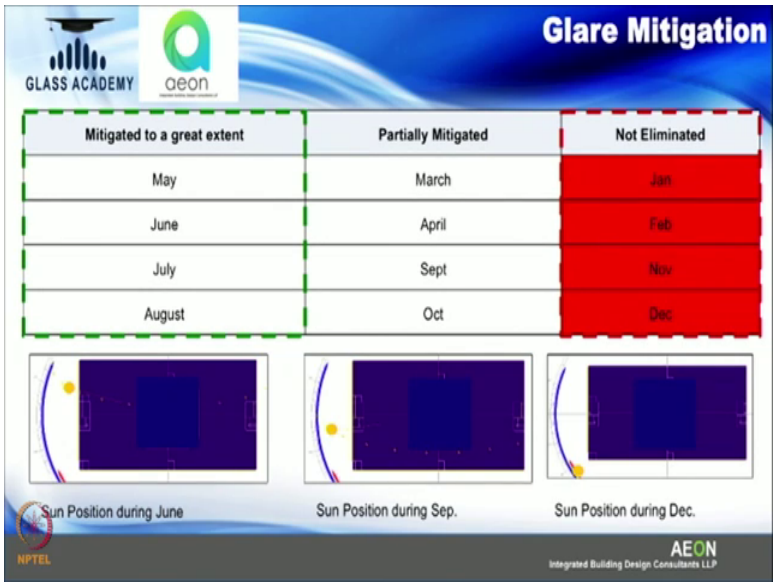
	Glare Timings	Office Operational Timings	Effective Glare Duration (During office timings) from South Side
January	1:15 PM to 6:15 PM	9 AM to 7 PM	5 Hrs.
February	1:15 PM to 6:15 PM	9 AM to 7 PM	5 Hrs.
March	1:15 PM to 6:15 PM	9 AM to 7 PM	5 Hrs. 15 Minutes
April	1:15 PM to 6:45 PM	9 AM to 7 PM	5 Hrs. 30 Minutes
May	1:00 PM to 6:45 PM	9 AM to 7 PM	5 Hrs. 45 Minutes
June	1:15 PM to 7:00 PM	9 AM to 7 PM	5 Hrs. 45 Minutes
July	1:15 PM to 7:00 PM	9 AM to 7 PM	5 Hrs. 45 Minutes
August	1:15 PM to 7:00 PM	9 AM to 7 PM	5 Hrs. 45 Minutes
September	1:00 PM to 6:30 PM	9 AM to 7 PM	5 Hrs. 30 Minutes
October	12:45 PM to 6:00 PM	9 AM to 7 PM	5 Hrs. 15 Minutes
November	12:45 PM to 5:45 PM	9 AM to 7 PM	5 Hrs.
December	1:00 PM to 5:45 PM	9 AM to 7 PM	4 Hrs. 45 Minutes

We did the similar exercise for West facade also there was about 5 to 6 hours glare from the west side for almost entire year which is critical to deal.

(Refer Slide Time: 17:47)

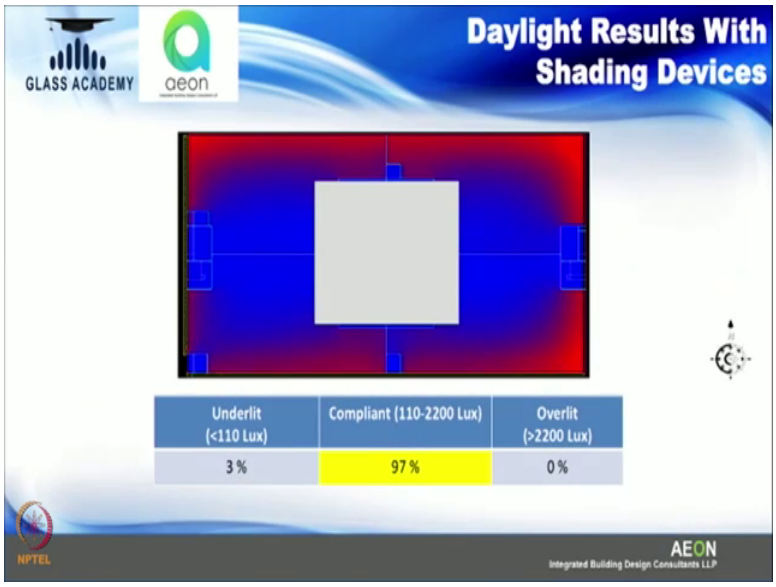
And we did the similar accesses of optimising the facade from the glare mitigation point of view, different options of shading were proposed there.

(Refer Slide Time: 17:59)



And it actually got mitigated for almost all the months except for the winter season again because of lower sun angles, but that is something which rather than over shading it is better to use a different approach for only those very critical time.

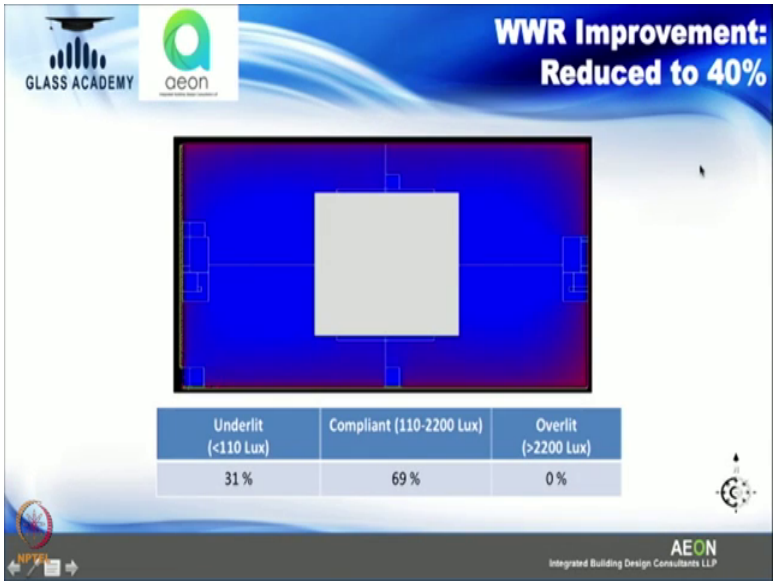
(Refer Slide Time: 18:24)



Then with a shading devices what happens is that are daylight also get affected. So, we did the daylight analysis again to see how much is the effect on the daylight that we are getting because of shades. So, in this particular case our compliant areas were actually coming out to be 97 percent because, the shading is optimum. But, we started working

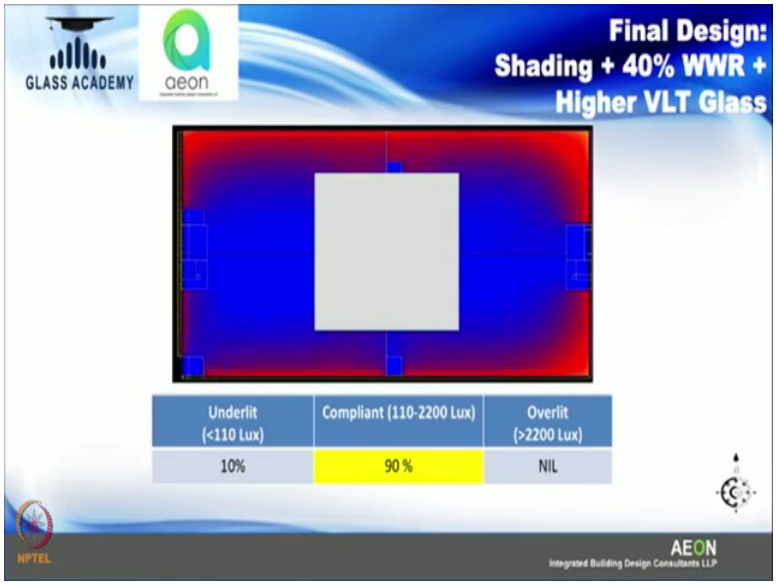
on even the WWR because the WWR was high we intend to even reduce that so, that our energy consumption can also be controlled.

(Refer Slide Time: 19:03)



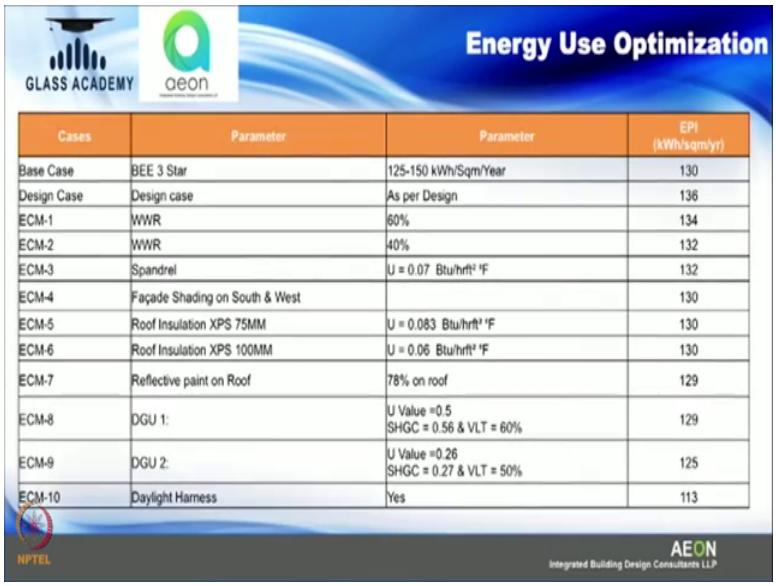
We reduce the WWR to 40 percent which is what even the different standards ask for and so, there is a decline in the usable daylight areas from 97 to 69 percent.

(Refer Slide Time: 19:18)



Within to compensate that we can go with the higher VLT glass and with that higher VLT shading and optimise WWR which solves all the purposes we are at 90 percent daylight areas.

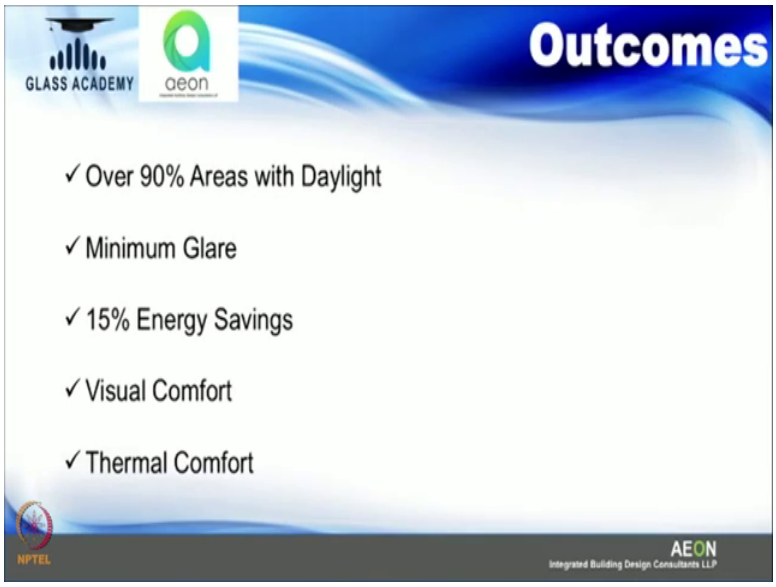
(Refer Slide Time: 19:39)



Cases	Parameter	Parameter	EPI (kWh/sqm/yr)
Base Case	BEE 3 Star	125-150 kWh/Sqm/Year	130
Design Case	Design case	As per Design	136
ECM-1	WWR	60%	134
ECM-2	WWR	40%	132
ECM-3	Spandrel	U = 0.07 Btu/hrft² °F	132
ECM-4	Façade Shading on South & West		130
ECM-5	Roof Insulation XPS 75MM	U = 0.083 Btu/hrft² °F	130
ECM-6	Roof Insulation XPS 100MM	U = 0.06 Btu/hrft² °F	130
ECM-7	Reflective paint on Roof	78% on roof	129
ECM-8	DGU 1:	U Value =0.5 SHGC = 0.56 & VLT = 60%	129
ECM-9	DGU 2:	U Value =0.26 SHGC = 0.27 & VLT = 50%	125
ECM-10	Daylight Harness	Yes	113

Even the energy use optimisation study we did.

(Refer Slide Time: 19:45)



And found that you know by doing different strategies we were able to actually get all these outcomes of over 90 percent area with daylight with minimum amount of glare. Energy savings were achieved for about 15 percent and visual comfort, thermal comfort all the targets are achieved.

(Refer Slide Time: 20:07)

This is another case study where you know it is a commercial office building coming at Noida. It is very interesting building where the envelope optimisation has been dealt with very carefully and it is a very ambitious building which is coming up. And what are the basic outcomes if you really see here you have got 360 degree daylight in all the areas. The entire building is daylight adequately, we have got very comfortable daylight level inside the building with absolutely no glare.

So, the facade that you see this is all screens, it is a dual skin facade and there is a as high as 40 percent load reduction which was achieved only by envelope. Over 30 percent energy savings, renewable energy is getting integrated and the target rating over there is of course, platinum.

(Refer Slide Time: 21:16)

Some of the very good features which have been incorporated in this building it is a courtyard planning, there is a central courtyard which works like a daylight well also and a ventilation shaft also. So, it is something which is you know as a passive measure which has been incorporated in the building.

Dual skin facade so, there is glass facade outer facade is basically a screen which is a specially designed you know anti glare screen, a lot of focus was given to have the glare free daylight. So, light shells are also design on one of the sides of the internal courtyard. So, there was glare coming from one side of the courtyard which is what has been optimised by using light shelves. It also helps in increasing the daylight levels for that particular area because, the light is reflected deeper into the float light.

Insulated exterior walls, double glazing units, insulated roof with reflective surface. Now, in this particular case I would also like to add is basically when we were doing all that optimisation about the window to wall ratio and you know shading coefficients and everything as I showed earlier. we went with a high WWR, but we shaded the entire facade.

Still, views are not that compromise because there are deep balconies provided the between the 2 skins which have got the vegetation, which works like providing oxygen into the environment inside the building. So, it is quite a different feel from the inside where not only the heat ingresses taken care of, but also the health income for aspects of

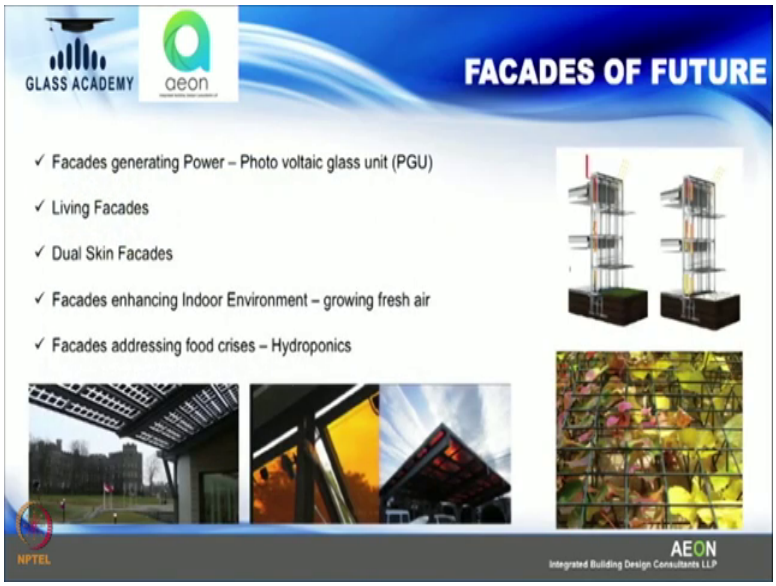
the people have been dealt properly.

(Refer Slide Time: 23:21)

These are the building is under construction is, these are some actual photographs which you can see how this is coming up and it is going to be really a good building in terms of really seeing how the building envelop can be optimised. And you will see on this facade there are a few areas which have which are like more researched areas with no screens in front.

So, the glass selection was done accordingly, it is not just one type of glass which is used there are multiple types of glasses used on the glazing. So, that we are thoughtful about where to go higher, where to go lesser, where VLT's higher, where shading coefficient is lesser. So, all of that combination has been used to arrive at the very optimum design that we have.

(Refer Slide Time: 24:19)



Beyond that there are many facades for future also the concept which are going on. Facade generating power is definitely something which is a concept coming up where we use the facade to generate electricity. So, we are designing net 0 buildings where the solar panels are integrated on to facade because, roof areas are getting minimised it is especially when you go taller in any building. So, there the opportunity becomes to generate power on the facade. And the building envelop integration with solar panels gives you the opportunity to you know use the panels to your best advantage of having the daylight optimisation, the heat ingress, the glare and also the energy generation.

There is concept of living facades where you know the greeneries being used on the facade, green walls are used. Dual skin facades, we already have one example, we saw in the last case study this also a concept of within the dual skin facades you ventilated. So, that the heat ingress is you know minimised in through the second skin.

Facades enhancing in a indoor environment, growing fresh air, facade addressing food prices which is through hydroponics. So, a lot of these concepts are actually very much prevalent in the buildings that are coming up and are going to come up in future. We have to be thoughtful and mindful of the fact what do we want to achieve of out of the building envelop and how do we best optimise the performance. There cannot be one sides fit all approach because, every building has got it is own dynamics. Its location is different, its sizes different, scale is different, usage is different, occupancy patterns are

different maybe even the schedule of operations are different.

So, it has to be taken into a more customised manner what do we design for a particular building depending on all of those factors. There are many tools available which can really give us the desired outputs and tell us work like a design guidelines or design tools for us to give us the right figures and numbers to tell us what is right, what is not right. It is better to make use of the tools.

No more thump rules or guest mates are required because those tools are there, it is better to utilise that. And I think more and more of the building efficiency and the other dimension which are coming up now about the wellbeing in comfort and health of people those have to be integrated along with energy efficiency that is it.

Thank you.

(Refer Slide Time: 27:36)