

Glass in buildings: Design and Application
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Lecture – 14
Design Tools for Glass Section

Daylighting analysis; so we have considered the geometric design aspect in the sun path by a studying the shading etcetera. And we also know by the impact of glass on your energy savings by using your whole building simulation.

Next comes your visual comfort; where you need to have daylight natural daylight enter into your building through your building openings in your building envelop.

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DAYLIGHTING

NPTEL
GLASS ACADEMY

1. Point In Time metrics
2. Annual metrics / CBDM

Point In Time Metrics:

- Point in Time Illuminance -> Lux level inside the room at a particular point in time
- Daylight Factor – Illuminance in the room as a factor of ambient lux level

Annual Metrics:

- Daylight Autonomy(DA) – How much % Floor area is above a particular lux level for a particular % of time in the year
- Useful Daylight Index(UDI) – Annual metric(Like DA) with upper and lower limit
- Annual Solar Exposure(ASE) →

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- SDA (50-1) 150
- UDI (300-3000) 100
- 107 => (1000lux)
- ⇒ Floor area

Presentation title

So, there are different metrics to understand that of in daylighting. So, the different daylighting metrics are listed here. So, there are two types broadly we can define; one is a point in time metric for example, what is a daylight metric at a particular point in time say 21st September 12 p m ok. So, that is a point in time metric and the annual metrics which considers the entire year into your simulation, and it let us know how much will be the daylight that is coming inside.

So, let us see one by one, first in point in time metrics. One typical you know metric that is used often this year point in time illuminance where you will understand how much is the lux level in your floor plate or your working plane at a particular point in time.

And next is your daylight factor. So, a daylight factor has a very clear explanation I will give you in the next slide. So, to be to understand it roughly, it is nothing, but your how much light illuminance is there inside your building compared to the illuminance outside. So, this is just for your rough understanding. So, it is a percentage it is a factor it is a percentage represented in percentage.

Next is your annual metrics, where we have three annual metrics here one is your daylight autonomy, second is your useful daylight index and annual solar exposure. So, daylight autonomy is nothing, but how much percentage of floor area gets a particular minimum lux level, when you run the simulation for the annual. Say for example, saying that at least 50 percentage of the time of the year your floor area should get above 300 lux. So, this is a daylight autonomy criteria given by a rating system. So, you need to understand that using a simulation. So, that is your daylight autonomy; so for example, ICA SDA 50 percent 300. So, this is nothing but for 50 percent of the time that you are running a simulation, how much percentage of floor area gets a lux above 300. So, that is your SDA ka understanding. So, this is your daylight autonomy.

So, next is your UDI. So, I have said that this is 300. So, when this is having an upper limit; so from 300 to 3000 or say from 100 to 2000. So, what is the percentage of floor area when it runs a stimulation for so much has of time that is your useful daylight index.

So, as the name suggests this is the range which you can understand as useful daylight when it goes below your 100 lux it will be very dark. If it goes say above your 2000 or in the range of your 2000 or 3000 you will have some visual discomfort because the contrast ratio will increase. So, from when you are viewing from one point to when you are seeing a 2000 or 3000 lux. So, you will have face a high contrast and you will face some glare. So, that we say as visual discomfort.

So, the useful lux level is between this range. So, that is why it is called as a useful daylight index. So, the difference between your daylight autonomy and is that daylight autonomy has only one limit threshold whereas, your UDI has a lower and an upper threshold and another one is your annual solar exposure. So, this is a particularly

important in your lead rating, where they say that the max they said the maximum limit. This is like your minimum limit say 300. So, that should satisfy and the maximum limit should not go beyond 1000 lux. They say that when you run the simulation not more than 10 percent in the particular lead rating they are saying that, not more than 10 percent of the floor area should have above a 1000 lux level for wa say 250 hours of the simulation. So, that is what is annual solar exposure.

So, roughly you can understand. So, annual solar exposure is some the percentage of floor area that will undergo some discomfort. So, that is your rough understanding. So, these are the different metrics let us see some detailed analysis.

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DAYLIGHT FACTOR

3.3 Components of Daylight Factor -- Daylight reaching an indoor point comprises: (a) light received directly from the visible part of the sky, (b) light received directly due to reflections from external surfaces which are visible from the given point and (c) light received after inter-reflection between room surfaces. These components are also expressed as percentage ratio of the design sky illuminance on a horizontal plane outdoors. These are termed as sky component (SC), external reflected component (ERC) and internal reflected component (IRC) respectively. Daylight factor is obtained by adding up these three components.

$$DF = SC + ERC + IRC$$

The value of sky component is zero at any point on the horizontal ceiling of a room; it receives only ERC and IRC. For a single-sided room, the window wall receives only IRC, since the sky and external surfaces are not visible from any point on the window wall in case of windows on the same wall. The sky component is also zero beyond the 'see sky line' on a horizontal workplace. The values of ERC and IRC increase with the increase of reflectance of relevant external surfaces and internal surfaces of a room.

3.3.1 Direct sunlight is excluded from the definition of daylight factor, as it is not desirable from the viewpoint of lighting quality. It creates problems of harsh shadows and severe brightness imbalances resulting in glare. Direct sunlight also brings in undesirable heat in summer. Therefore, adequate shading devices are recommended not only for thermal comfort but also for visual comfort.

TABLE 2 RECOMMENDED DAYLIGHT FACTORS FOR INTERIORS
(Class 3-6)
(1 percent DF = 10 lux)

Sl. No.	LOCATION	DAYLIGHT FACTOR PERCENT
i) Dwellings	Kitchen	0.45
	Living room	1.0
	Study room	0.30
ii) Schools	Class room desk top	1.0-1.8
	Black board	2.0-3.0
iii) Offices	General	1.0
	Drawing, typing	2.0
	Enquiry	0.25-1.0
iv) Hospitals	General wards	1.0
	Physiological laboratory	2.0-3.0
v) Libraries	Stack room	0.8-1.0
	Reading room	1.0-1.5
	Common area	2.0-3.0
	Catalogue room	1.0-2.0

Handwritten annotations in red ink:

- ← Sky component
- Ext. Ref. Component
- Int. Ref. Component
- SP 41 standard

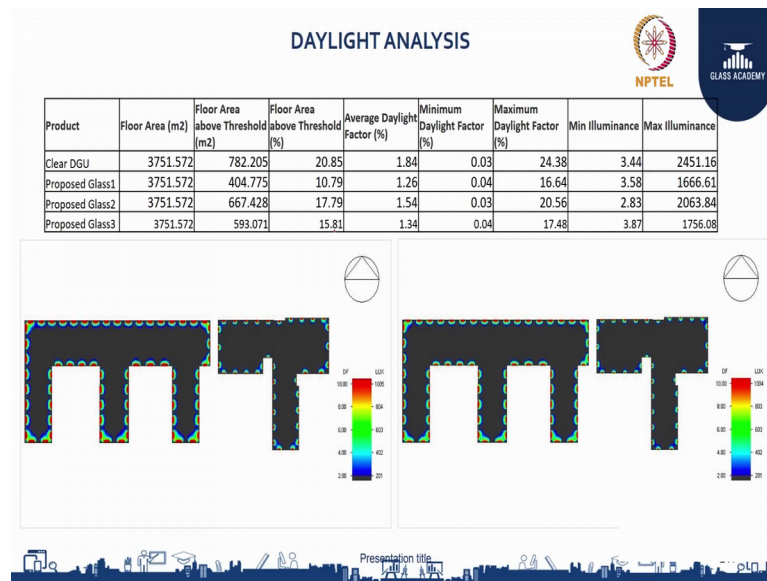
So, first is the daylight factor. So, there is this standard called SP fa 41, which gives you a detailed calculation of daylight factor.

So, in daylight factor there are critically three components one is your solar components, this is a sky component, next is your external reflected component another one is your internal reflection component. So, this is what we get as direct sunlight from the sky and this is nothing but the illuminance that you get because of reflecting surfaces from the outside and this is because of the illuminance you get from the reflected surfaces on the inside of the building.

So, they have given a detailed calculation you can refer to this standard for how to calculating the how to calculate the daylight factor in a particular room and they have also given some thresholds as to what will be the comfortable daylight factor.

For example if you take a kitchen and you calculate the daylight factor as per SP 41. If you have 2.5 as your daylight factor it is comfortable. So, this is what your SP 41 deals with when it comes to daylighting.

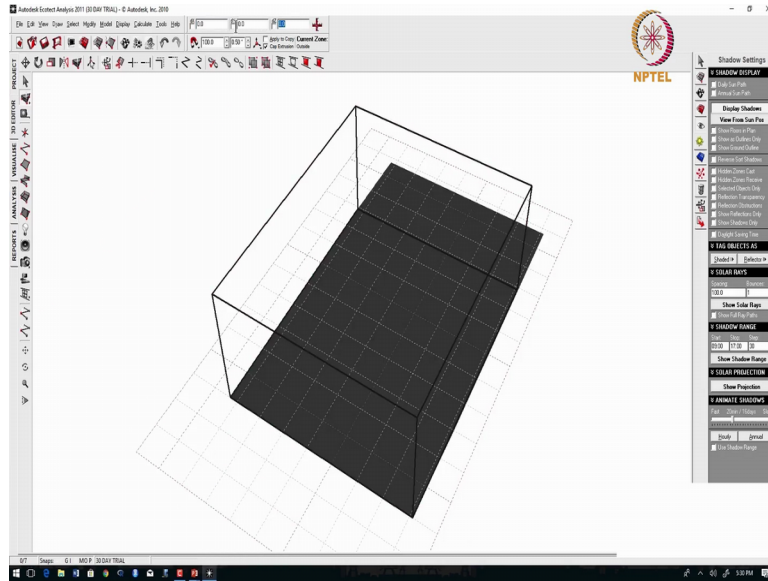
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So, we can go through that and one more option instead of the manual calculation given in SP 41 is your analysis. So, your there are many tools available which can tell you what will be the daylight factor and what will be the lux level when you simulate for a typical floor. So, I will take you through one such case study.

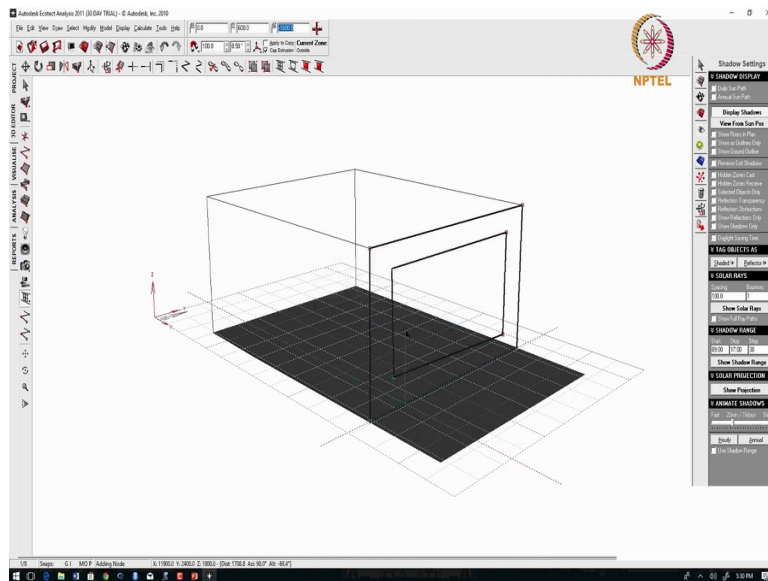
So, I am opening a new ecotech project and I am just modeling a small room.

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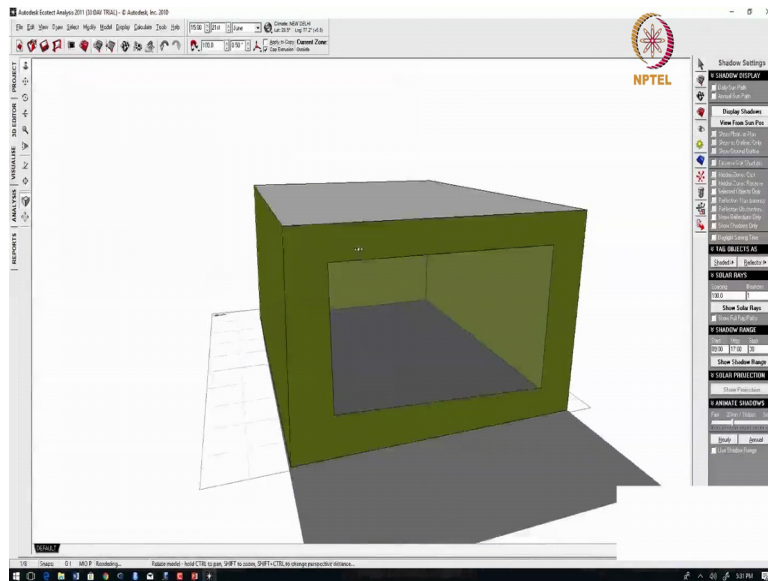
So, I am giving an extrusion of say 4000 mm say the floor to floor height you say 4 meters.

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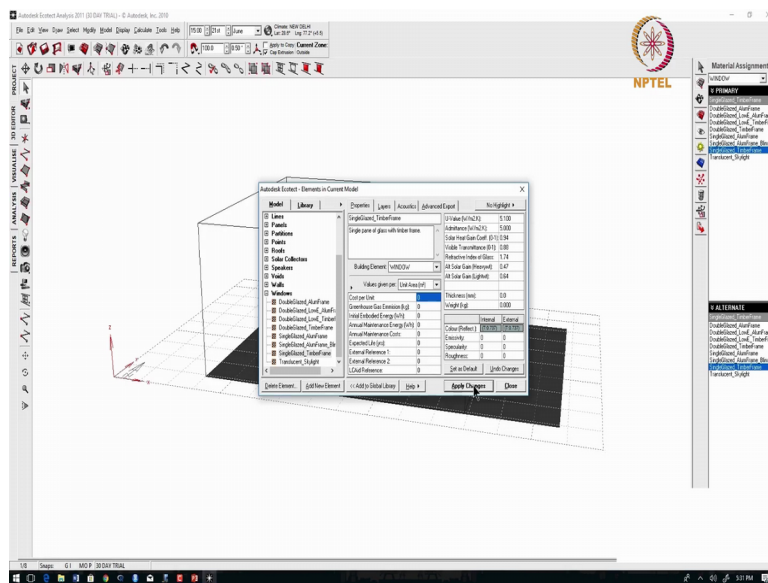
And I am going to model a window. So, I will just made a rough model of a window. So, I can go to visualize and see.

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So, this is a window that has been modeled. So, I can go and set the visual light transmission. So, I am selecting that window go into materials.

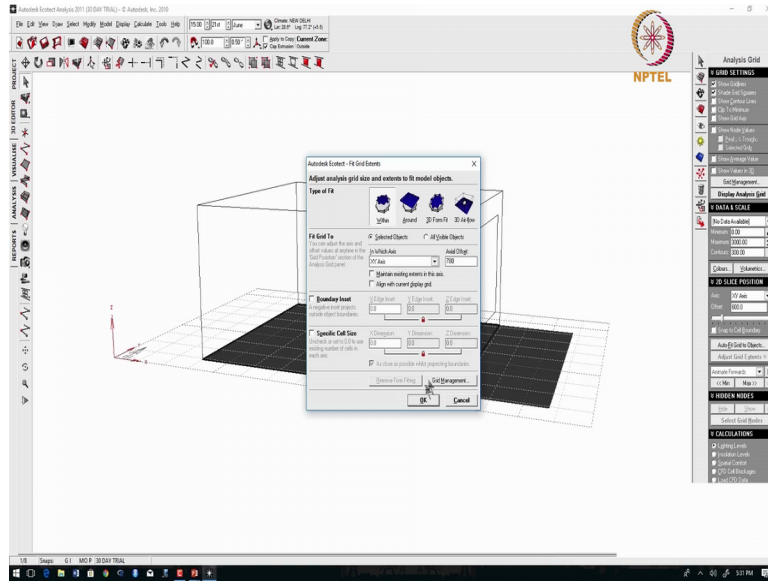
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When I double click on it you can see all these properties over here. So, in this I am entering the visual light transmission say 0.8. So, this is a vlt of single glaze clear glass.

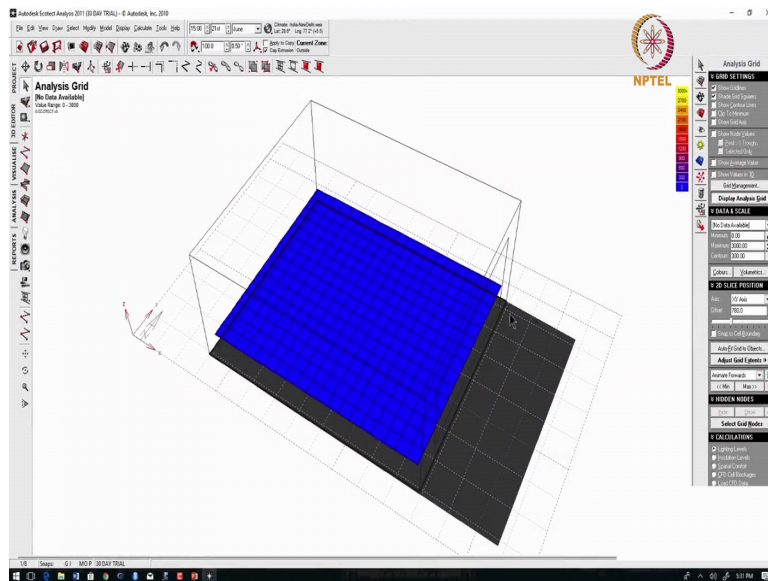
Now, I am selecting the floor plate and I am going to give the analysis grid.

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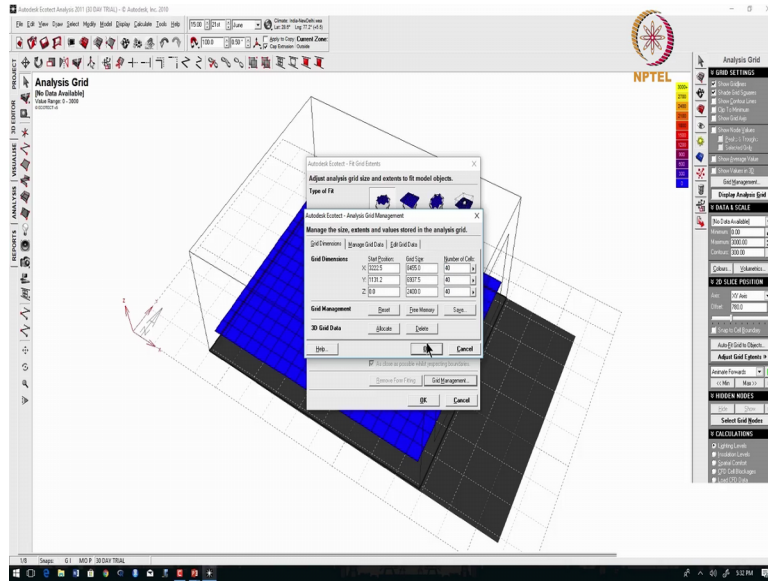
So, here you can see that part of it grid objects. So, here I am going to give the working plane say 780 mm.

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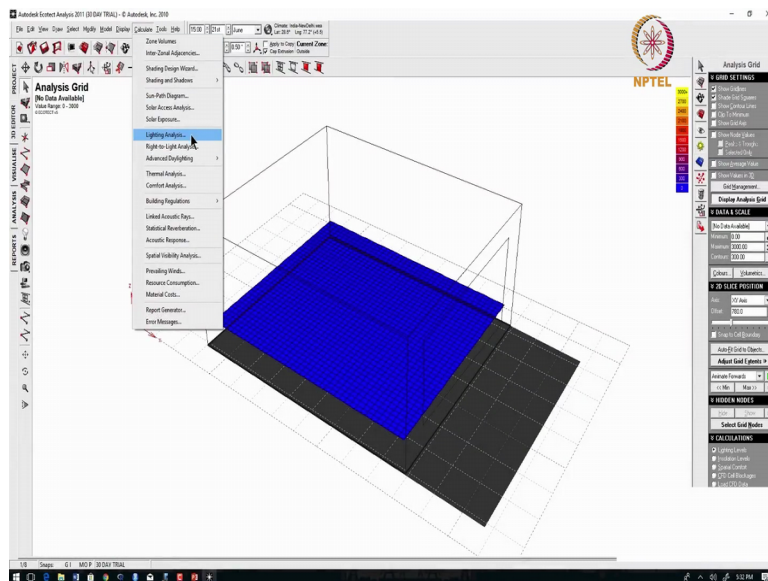
So, I can see a analysis grid here.

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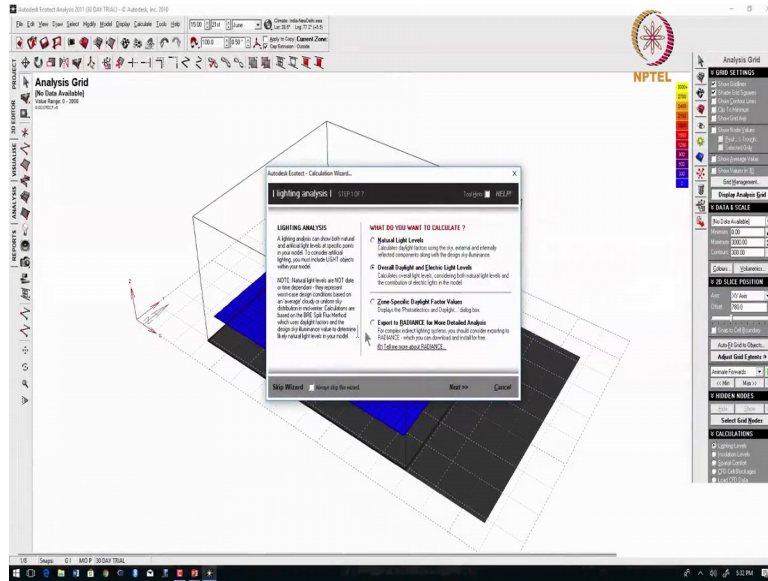
So, I can also increase the number of you know the grids that are going to come inside say I am going to give 40 ok. So, you can see that the grid has resize depending on what I gave as inputs.

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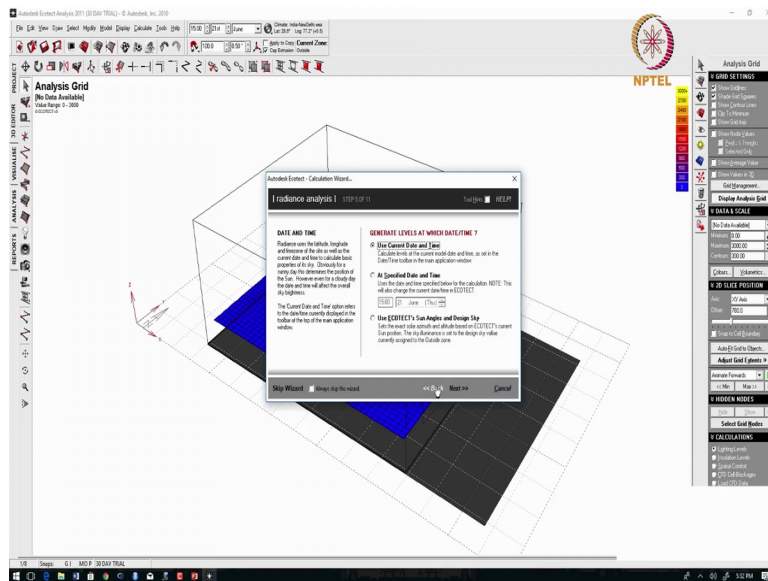
And now, I am going to run a small simulation calculate lighting analysis.

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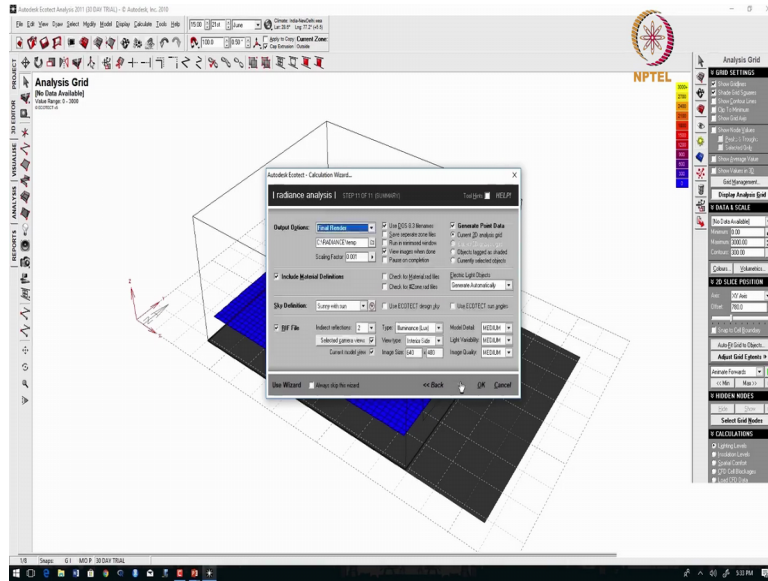
So, there are two options: this is directly doing in ecotech and this is through radiance. So, for this you should have installed this plug in called radiance.

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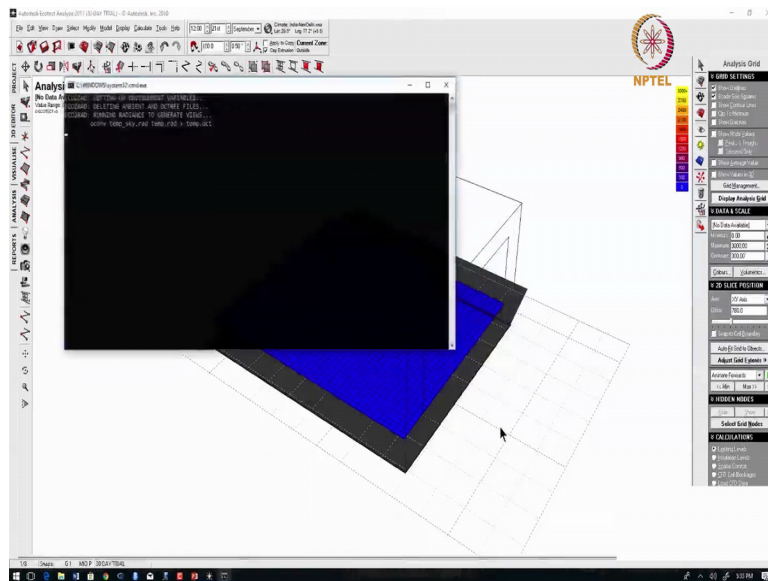
So, I am doing for the sunny sky, let us see; what is the lux level. So, I can also select what is the time I want the simulation say 12th September; 12th September 21st September and 12 hours.

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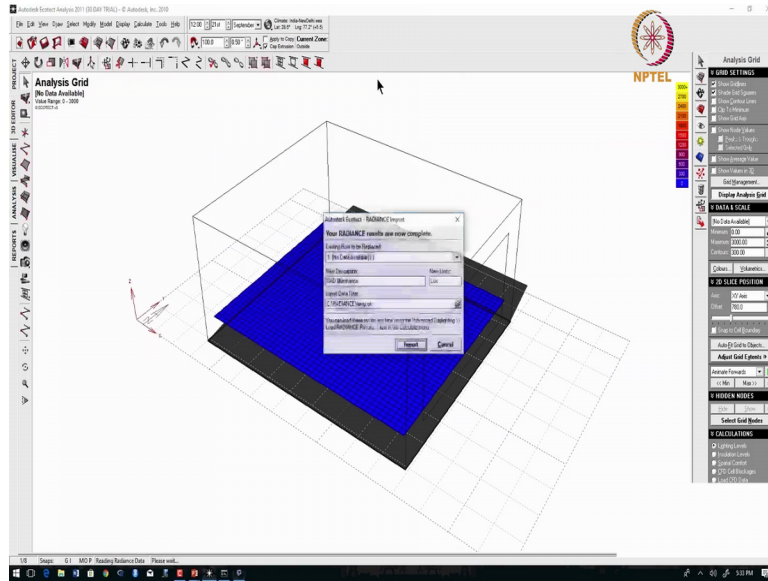
So, this is the setup of we are setting up this tool radiance. So, for detailed you know tutorials you can refer to the link that I have given.

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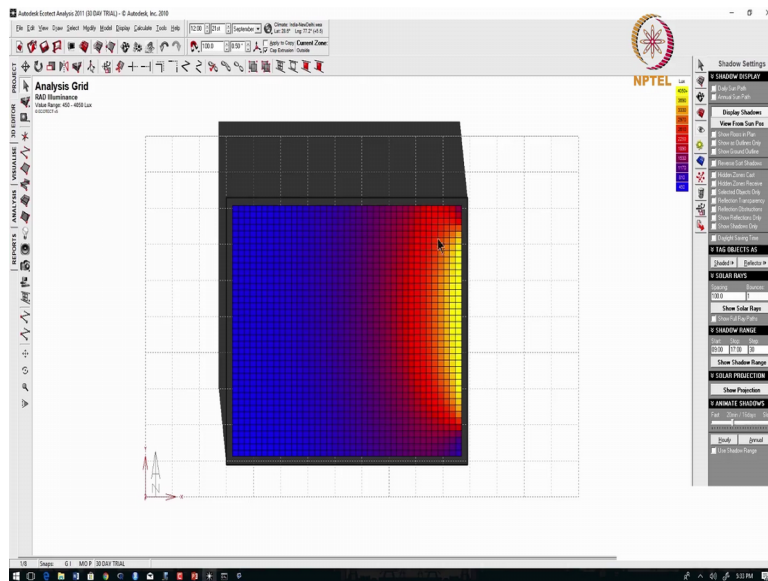
So, it runs in the background, the radiance engine is running in the background, but the modeling we have done in ecotech. So, there are many other tools that you can use for daylighting, but radiance is something that is freely available.

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I think ecotech currently it has been stopped, there are many other alternatives for doing this analysis as well

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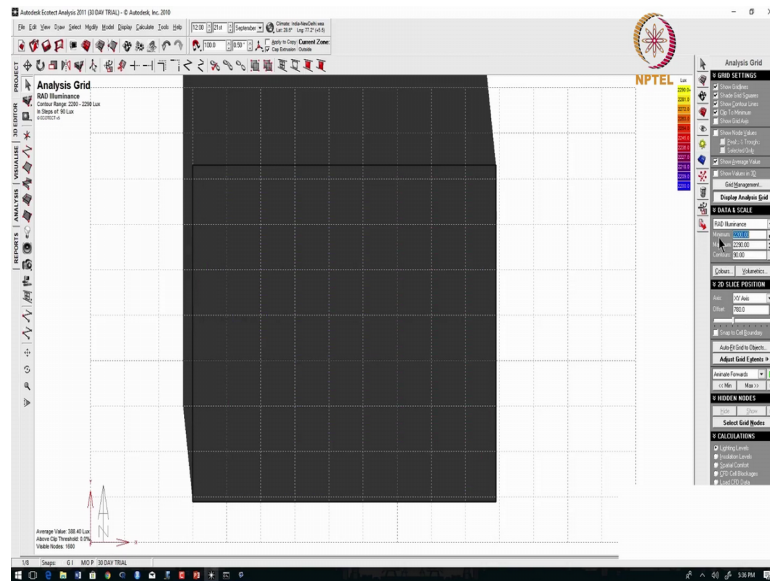
So, once it is imported, you can see that from the window the maximum lux goes as high as 4000 lux. So, I can even go and change see how much area is above a particular lux level. So, here I am giving flip to threshold. So, the average lux level is 1300 and 100 percent of the area is above your 110 lux.

So, next say I want to see for 2200 lux.

glass has a vlt of say 0.3 right. So, again I am selecting this floor plate and I am going to redo the analysis.

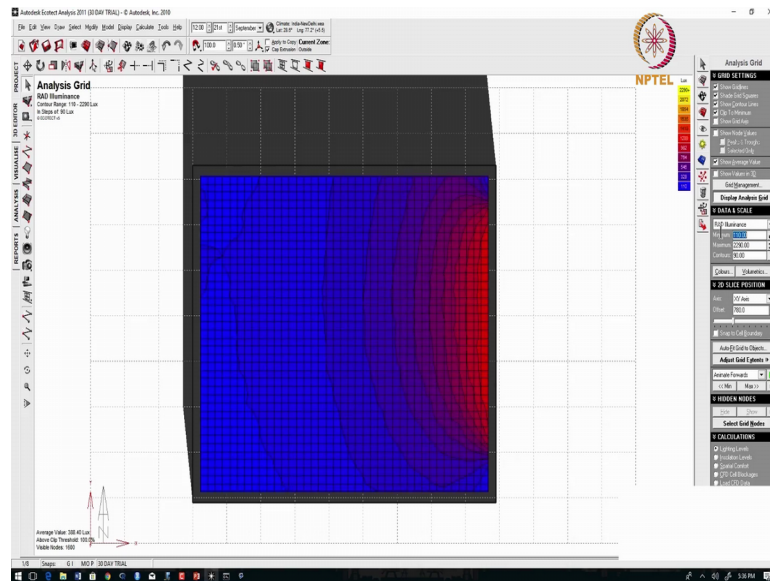
So, now you can see on the left hand bottom that the average lux level has gone down from as high as 1300 lux to around 388 lux. And also you check; how much is the area that is above 110 lux. So, almost 100 percent of the areas above 110 now I am giving 2200.

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So, 0 percent of the area is above 2200 and one more check we can do say 1100 we can check about what lux level.

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So, your maximum lux level goes up to 2000. So, what is the takeaway from here is like when we use different visual light transmissions we can understand; how much will be the average lux that is entering inside and also understand the distribution of light.

So, here it is showing a small gradient, where 110 lux is shown in blue and as we go higher the maximum lux that comes here is in the range of 700 to 900. So, you can see the color coding here and it might go as high as 1000 lux level. So, depending upon your location depending upon the orientation we need to change different vlt ranges and check; which is the comfortable range

So, how do we know this range which is comfortable or not?

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DAYLIGHT ANALYSIS

❖ **Option 1: Simulation Approach**


Demonstrate through computer simulation that 75% of the regularly occupied spaces in the building achieve daylight illuminance levels for a minimum of 110 Lux (and a maximum of 2,200 Lux) in a clear sky condition on 21st September at 12 noon, at working plane.

Areas with 2,200 Lux or more daylight illumination levels should not be considered.

Points are awarded as below:

Percentage of Regularly Occupied Areas with Daylighting	Points
≥ 75%	1
≥ 95%	2

**IGBC- NEW BUILDINGS
IEQ CREDIT 2**

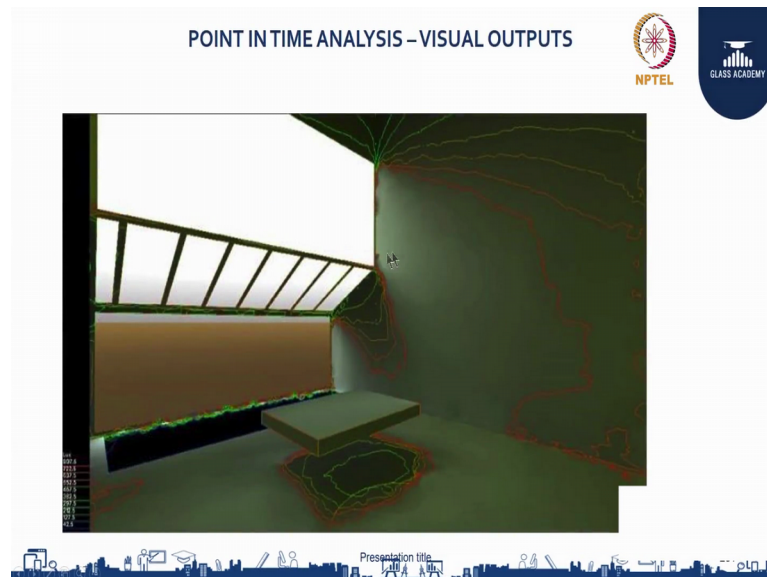


So, for that we have some directions from you know the green building rating system or some common rating systems, which tell you what will be the comfort level. And above what point if you above what particular threshold if your light is coming inside you will get some points.

For example this is one such criteria from IGBC, which says that demonstrate through computer simulation that 75 percent of the regularly occupied spaces in the building achieve daylight illuminance level. For a minimum of 110 lux and a maximum of 2200 lux in clear sky condition on 21st September at 12 noon. So, this is what we have done? So, we have taken the working plane which is around 780 mm and we had set the date to this particular day, and we set these two thresholds calculated how much is the area percentage area.

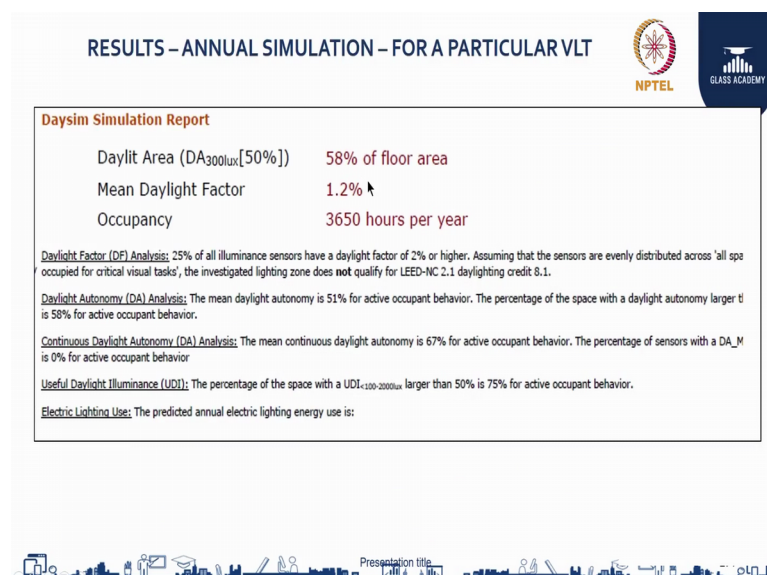
So, in the first case it was in a different level and in the second case it was in a different level, from that we can understand which product we will satisfy or the which vlt range we will satisfy this particular requirement.

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So, this kind of visual outputs can also be taken, to understand what will be your contour lines at different areas from a three d point of view for example, here you can see that the different areas in the wall get, different dispersions of the lux level coming inside. So, here we have the legend say for example, this is this area is getting around 900 lux whereas, it is going down as we go towards the center. So, this is one output that we take out of radiance.

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So, next is your annual simulation this is quite similar, but you depending upon the definition we get the output. So, for example, you want the daylight autonomy for 300 lux and 50 percent of annual hours, you can understand how much percentage area is

getting this condition. So, this is an output from daysim. So, daysim is a software that will give you annual simulation. So, radiance this is a again radiance you can use for point in time simulation daysim is more helpful in terms of your annual simulations.



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REQUIREMENTS FROM GREEN BUILDING RATING STANDARDS

Alternative 1	Alternative 2
<p>The WWR and SRR to not exceed 60% & 5% respectively &</p> <p>All the fenestrations meet the SHGC requirement of ECBC-2007/Weighted Façade average SHGC (for each orientation) meets SHGC requirements of ECBC-2007</p> <p>OR;</p> <p>Alternatively use Tables 9 & 10 of SP 41 to design the shading device for the windows. OR,</p> <p>Conduct solar path analysis for windows of AC as well as non-AC spaces, to ensure that the window is completely shaded for the duration between 10:00 am on 1st April to 15:00 on 30th September OR;</p> <p>Any combination of the above strategies on 100% of the fenestrations – Mandatory</p> <ul style="list-style-type: none"> • Minimum of 25% of the living area should meet adequate level of daylight (daylight factors) as prescribed in SP 41 – Mandatory • If the adequate daylight factors are achieved in more than 50%/75% of total living area - 2.14 points 	<ul style="list-style-type: none"> • Demonstrate that the mean DA requirements (200⁺ lux or more) are met over the total living area for at least 25% of total annual analysis hours (area-weighted) – Mandatory • Demonstrate that the mean DA requirements (3000 lux or more) are never exceeded over the total living area for across the total annual analysis hours – Mandatory • Demonstrate that the mean DA requirements (200⁺ lux or more) are met over the total living area for at least 50%/75% of total annual analysis hours (area-weighted) – 2.14 points annual analysis hours – 800 to 1800 each day

GRIHA CRITERIA 11




Presentation title


So, why this annual metric is important? You can see that this is again another snapshot from a green building code on the right there are two alternatives to achieving it on the right side. They have given the alternative saying three 100 the daylight autonomy of 300 lux or more should be the met in your living area for at least 25 percent of your annual hours. So, depending on this you can run a simulation and see how much percentage is satisfying these criteria.

And they have also given a upper limit, it should not go beyond 3000 lux. So, when you go beyond this 25 percent say 50 percent or 75 percent you get more points.

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REQUIREMENTS FROM GREEN BUILDING RATING STANDARDS

Requirements

Provide manual or automatic (with manual override) glare-control devices for all regularly occupied spaces. Select one of the following three options.

Option 1. Simulation: Spatial Daylight Autonomy (2-3 points, 1.2 points Healthcare)

Demonstrate through annual computer simulations that spatial daylight autonomy (sDA) of at least 55%, 75%, or 90% is achieved. Use regularly occupied floor area. Healthcare projects should use the perimeter area determined under EQ Credit Quality Views. Points are awarded according to Table 1.

Table 1. Points for daylight floor area: Spatial daylight autonomy

sDA (for regularly occupied floor area)	New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, CI, Hospitality		Healthcare	
	Points	sDA (for perimeter floor area)	Points	sDA (for perimeter floor area)
55%	2	75%	1	
75%	3	90%	2	

AND

Demonstrate through annual computer simulations that annual sunlight exposure (ASE) of no more than 10% is achieved. Use the regularly occupied floor area that is daylight per the sDA simulations.

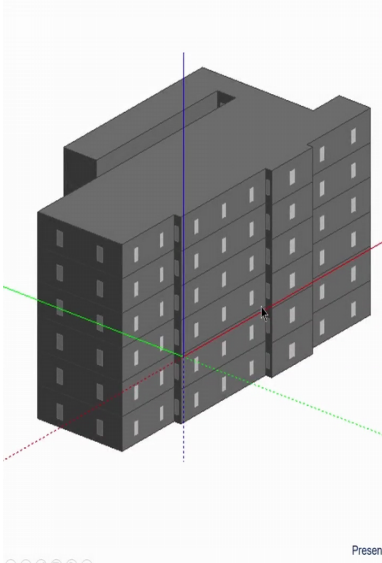
LEED v4 IEQ CRITERIA


Option 1

Presentation title

And this is one requirement from USGBC leed which talks about the same 350 and they are saying that it should be 55 percent 75 and 90 percent for different types of you know the different types of buildings like new construction or core and shell this is their typical rating system different rating systems are there, for schools they have a different rating system etcetera. So, for that if you get 55 percent and above, you get two points and 75 percent and above you get three points. So, this is these are all examples of different rating systems and how what importance they give for this kind of daylighting indices

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PANEL SIZE
OPTIMISATION

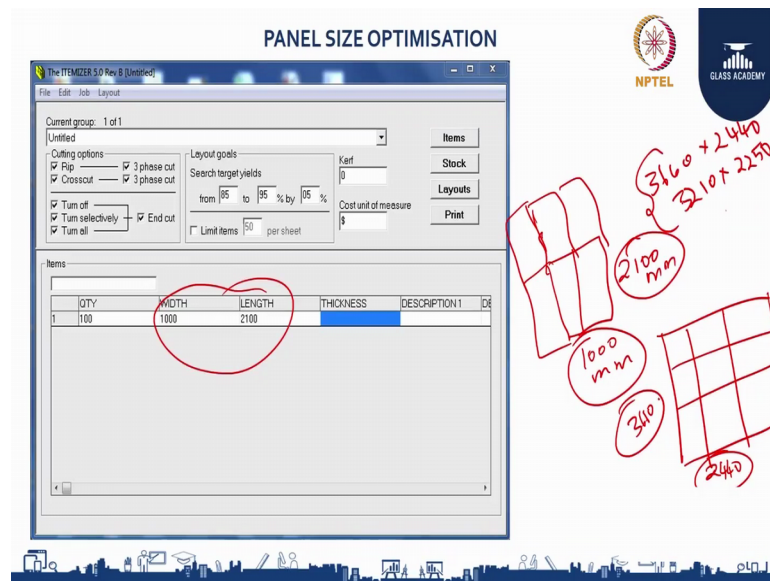
Presentation title

So, this is the end of your daylighting and next we enter into an interesting topic called panel size optimization. So, now, we have decided from the sustainability point of view

with the you know glass that I am going to use; whether it is going to be a coated glass of solar factor of. So, and. So, range. So, that I achieve my green building requirements or you get a comfortable lighting inside; so based on that you have decided on vlt solar factor etcetera.

Next comes a geometric properties which is your panel width panel height and your panel thickness of each glass.

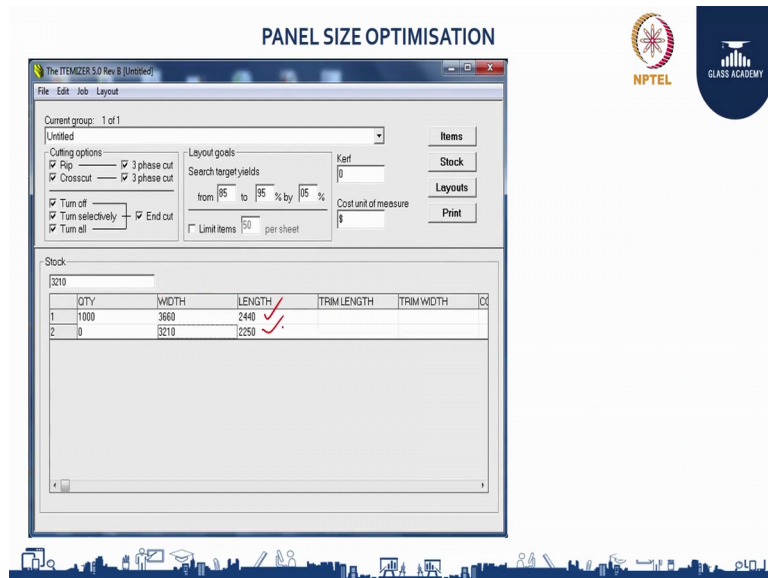
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So, why this is a criteria because depending on the panel size that you are using in a building the wastage that is going to incur from the panel size made by the manufacturer can be impacted. So, for example, I am taking a 1000 mm by 2100 mm panel. So, this is the panel that I am going to have throughout my building say 100 such panels are going to come.

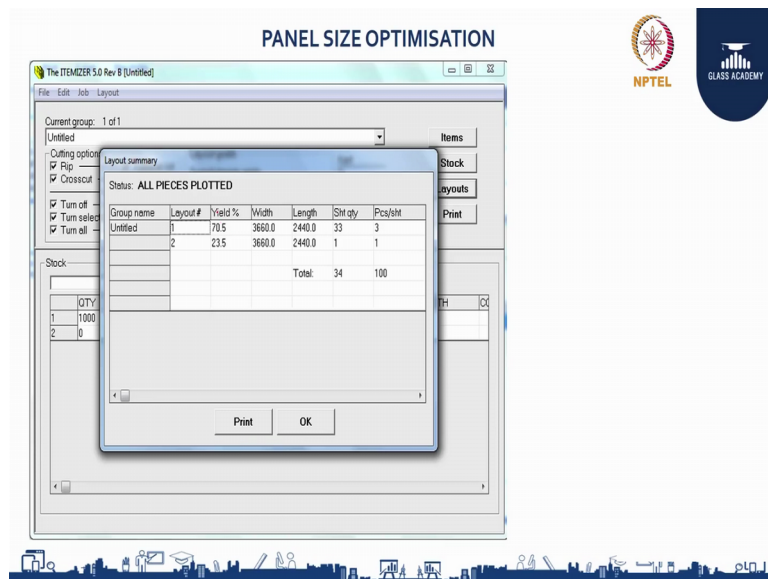
So, I have to cut this 1000 mm by 2000 on 100 mm from the sheet size supplied by the manufacturer, but the manufacturer will manufacture only in standard sizes say for example; one size is 3660 by 2440 say another size is 3210 by 2250. So, this is bigger or smaller. So, adjust that. So, based on this you need to cut. So, this 1000 mm by 2000 100 mm has to be cut from different sheets from the manufacturer. I will redraw it say for example. So, your 100 panels that you require here has to be cut from these panel sizes for example.

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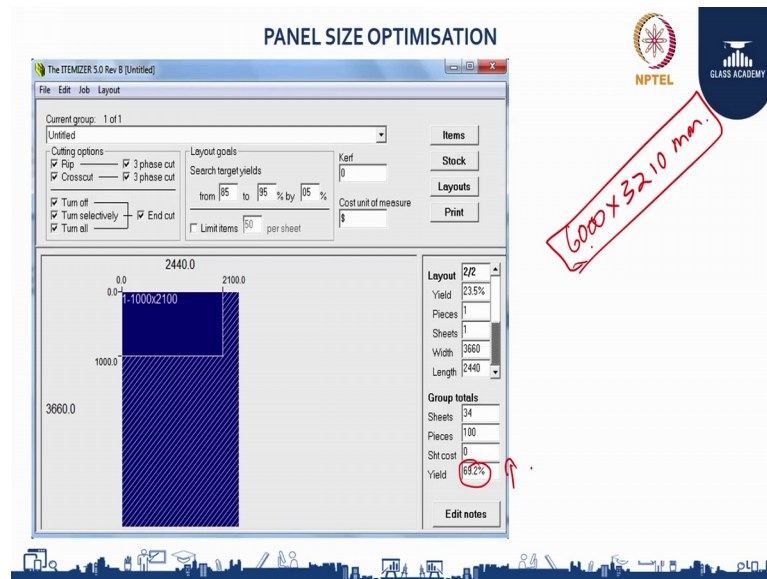
So, here I have entered those two panel sizes here.

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And now I am checking the yield how much percentage of this sheets are effectively utilized to take out this panel the remaining is going to be wasted.

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So, here I can see that the yield is going as high as 69.2 percent which means that the remaining 30 percent will not be used for the building, but they will be wasted. But as a client or a owner of the building they will have to pay for the entire parent sheet, the parent sheet of the glass that is supplied. So, to minimize the wastage that is incurring you need to increase your yield. So, when you increase your yield your wastage will get reduced. So, based on that if you resize your grid well close to accommodating the sizes manufactured by the manufacturer, then you can get a higher yield that is my point.

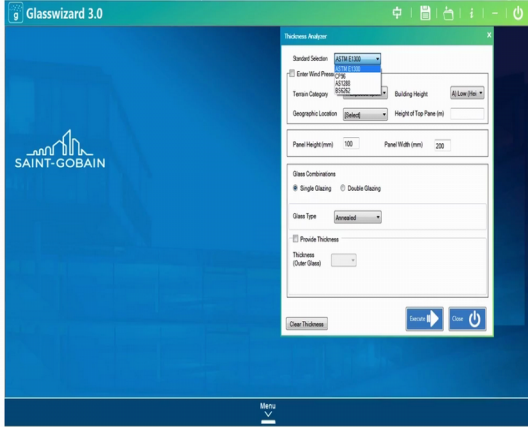
So, then based on that you can get a lesser wastage. So, there are even panels as high as 6000 mm by 3210 mm. So, this is one of the largest panels that can be manufactured in India. So, as high as this is available as a standard size

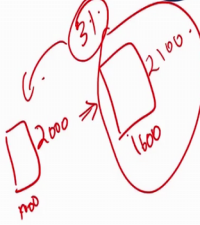
So, when you design the elevation of the building if you can consider even the manufacturing sizes by the manufacturer glass manufacturer that will give you a better yield and lesser wastage. So, this is one point that you need to consider.

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THICKNESS ANALYSIS







But one more thing is your safety aspect. So, when you are resizing your grid say from 1200 mm 1000 mm you are going to resizing it to say 1600 mm maintaining the same height. So, from 1000 d into 2000, I am increasing to 1600 into 2001 100 say for example.


So, this is matching with one of my manufacturers sizes and it has a very less wastage say 3 e percent or 4 percent say 5 lesser than your natural wastage. So, in that case your panel width and height are increasing. So, you need to check whether your glasses thickness is safe enough to take the load say take the same wind load.

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THICKNESS ANALYSIS

THICKNESS ANALYSIS




Glass Panel Data :	
Panel Size	1250 mm x 1245 mm ✓
Support System	Four Sided Support ✓
Cyclone Factor	1 ✓
Wind Pressure Considered	4 kpa (USER DEFINED) ✓
Glass Thickness Combination	6 mm + 0.38 mm PVB + 6 mm ✓

Analysis			
Actual Stress	16.95 N/mm ² ✓	Actual Deflection	6.84 mm ✓
Allowable Stress	31.52 N/mm ² ✓	Allowable Deflection (S,175)	2.14 mm ✓

Design is Safe

Standards Followed : Deflection Criteria as per ASTM - Maximum Deflection = Larger Span/175
Glass Combination as per AISI 1026

Comments :
ASTM Direct Wind Pt.



So, this kind of analysis needs to be done like for example: When you are increasing your panel width you are reentering that; what is the wind load, and what is the thickness combination that you selected then it gives you what is the actual stress what is the allowable stress what is the actual deflection and allowable deflection.

So, there are many standards available for doing such calculation and there is one tool called glass wizard, which does this calculation using the algorithms and the tables given in ASTM E 1300. So, this is one calculation which let us whether a particular thickness is safe enough to take the load or not

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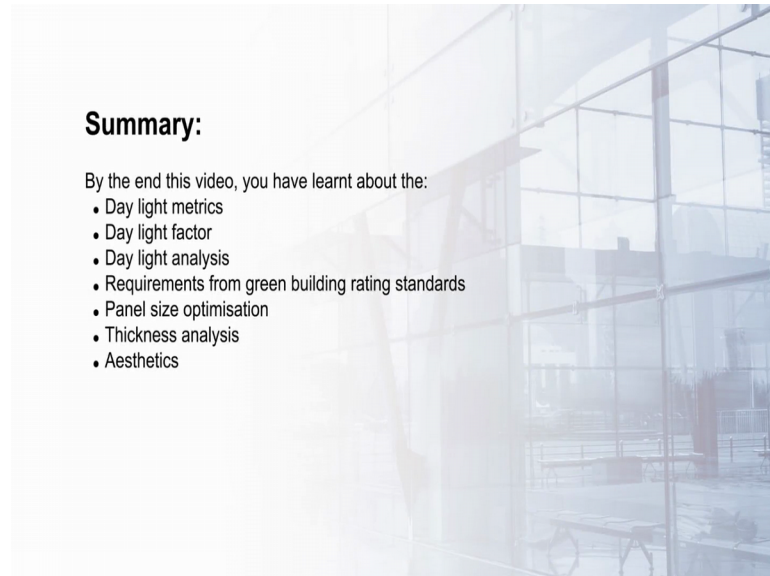


And so, we have covered the sustainability, we have covered the panel sizing, we have covered the thickness. And next is your aesthetics because considering all this. So, you will be installing a glass on your building and you need to understand how it will look.

So, there are many you know ways you can understand the aesthetics of glass one is through samples one is there will be mockups done and current digital technology available is there are apps available on your devices, a where you can go and just go and select a particular glass from here, and it will change the glass alone in this template. So, this is one app that is there called glass pro, it is available in our ipad app store where you can download, and see if you put a particular coated glass how it looks from a particular manufacturer alone.

So, there is also another method in which we can render the product in your in a particular design itself. So, that is also being done by some of the manufacturers.

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Thank you.