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Top Lighting for Enhancing Daylighting Performance in Drawing Studios

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Abstract:- Daylighting strategies are one of the most common aspects of architecture, but their proper use was ignored by the designers during the implementation of the educational buildings which led to the lack of distribution of Well daylit within the deep spaces. They find a lot of spaces have many windows and the absence of any external obstacles to entering the daylighting inside the space. But it has found some areas still dark, generate extensive heat gain and discomfort glare problems and this is not accepted in IES which ensures visual comfort, is one of the key design goals that architects and lighting designers seek; Due to the availability of cheap electricity at the time, the main dependence on space lighting was achieved by using the non-regulated electricity which led to the rapid increase in For this purpose, especially in deep spaces which asymmetric dimensional designed this paper aims to study the effect activating the use of top lighting strategies in educational establishments, especially the drawing rooms, which needs on the uniformity and availability of daylight and for long periods, to maintain the visual comfort of the application and rationalize the use of electricity using the techniques of the daylighting for the regular distribution of lighting. This investigation conducted by Generating the 3d models and analyzing the daylighting performance conducted through a parametric simulation approach. This approach included two software programs which are Grasshopper and Diva for Rhino. This Simulation consisted of two phases. The first phase investigated by achieved spatial daylight autonomy by use sawtooth systems on daylighting performance in four intermediate orientations. The second phase investigated using different shading techniques on enhancing daylighting performance and treatment of the annual sunlight exposure. Simulations were conducted using the weather data file of Alexandria, Egypt. The performance assessment was based on two metrics: IES approved method -Spatial Daylight Autonomy (sda) and Annual Sunlight Exposure (ASE). Results show that the northeast and northwest orientation for sawtooth opening with shading systems in Alexandria reached the required daylighting performance and achieved the acceptance criteria of the assessment metrics according to the daylighting requirements of IES.

Keywords:- *Educational Buildings; Draw Studios; Diva-For-Rhino Simulation; Grasshopper; Daylighting; Sawtooth; Skylight; Deep Space; Annual Sunlight Exposure; Spatial Daylight Autonomy .*

I. INTRODUCTION

Providing natural light in wide spaces is a crucial design issue for creating a healthy and pleasant for an educational environment while reducing the dependence on artificial light, hence, reducing energy consumption. In Alexandria where clear and sunny sky.

The science of daylighting design is not just how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects. Beyond adding windows or skylights to space, it involves carefully balancing heat gain and loss, glare control, and variations in daylight availability. Studies have shown that good daylight in an educational buildings is able to create a pleasant environment, enhance academic performance, promote better health and provide significant energy savings[1].This is sought by many countries to preserve the rates of their consumption of energy, the trend towards green architecture, sustainable design and environment-friendly buildings.

Other studies have looked at individual preferences at “light quality” indicators typically derived from luminance averages or ratios. Different daylight metrics concepts have been proposed, such as associated to entire space areas or viewed scenes rather than individual detection points and based on relative approaches for more complex systems. The latter helped to shift the focus back on daylight variability, not only its spatial distribution [2].

All ways of provision of daylight like Glazed openings for windows, glazed doors, skylights and other forms of top lighting, which can be referred to as "fenestration". What highly important in this process is the placement, design, and selection of materials for fenestration. These elements can tip the balance between a low performance and a high-performance building.

Fenestration affects the efficiency of building energy by impacting lighting loads, cooling loads, and heating loads. Skylights provide opportunities for natural ventilation. This is why they must be designed to ensure a safe, secure, and easily maintained facility. In this regard, skylights location, shading, and glazing materials play an important role in attaining visual comfort, where well-designed top lighting can be a visual delight.

On the contrary, the poorly designed lighting system can create a major source of glare. In addition to visual comfort, thermal comfort can also be affected by poor fenestration design. Whereas daylighting with low U-values helps in approaching or even equalizing the glass surface temperatures to the interior air temperature, which consequently improves the thermal comfort [3].
Sawtooth openings are system for ceiling used to control daylighting by allowing the penetration of indirect sun beam and redirect its rays and reflect them inside the space [4].

Orienting the sawtooth aperture away from sun direction provides the steadiest level of illumination with a minimum solar heat gain [5]. However, many studies reported that using sawtooth systems often results in providing the required natural daylighting uniform levels. Nessim a. (2017) investigated enhancing daylighting performance in an existing toplit educational space which is a north-east oriented toplit drawing hall, located in the city of cairo, egypt [6].

II. THEORITICAL REVIEW

A. Visual Comfort in Educational Space

A combination of daylighting strategies with shading strategies give the right design for a studio with natural lighting devices [7]. Light must be well distributed inside the studio when applying the natural lighting strategies, allowing its penetration into a given space. While designing, avoiding problems of solar radiation, glaring light, reflected sunshine glaring on the board, the desk, and walls should be carefully considered. Such problems can be avoided by using the overhangs and interior baffles. The quantity and distribution of the light can be managed by controlling the natural daylight. When planning daylight strategies, the floor plan should be with an east and west axis, and south facing windows and roof monitor and skylight for daylighting [8].

B. Lighting through the roof

In the case of multistory buildings, only one story or the top floor can use overhead openings, except for using light wells. When applying this method, horizontal openings (skylights) provide two main benefits:

These horizontal openings allow fairly uniform illumination over very big interior areas. On the other hand, the daylighting permitted from windows is found to be limited to about 4.5 m perimeter zone (Fig.1).

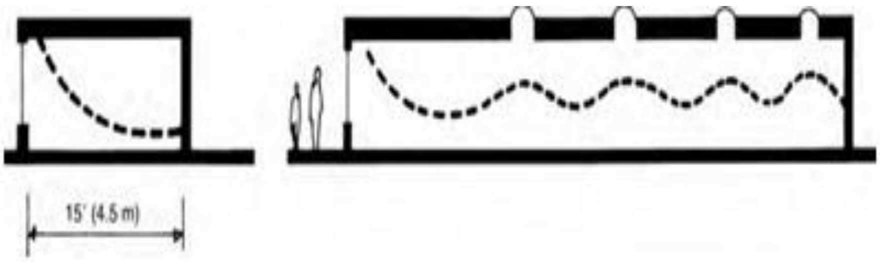

Fig 1:- While daylighting from windows is limited to the area about 4.5 m from the outside walls, roof openings can yield uniform lighting over unlimited areas.

More light is received via the horizontal openings than the vertical openings.

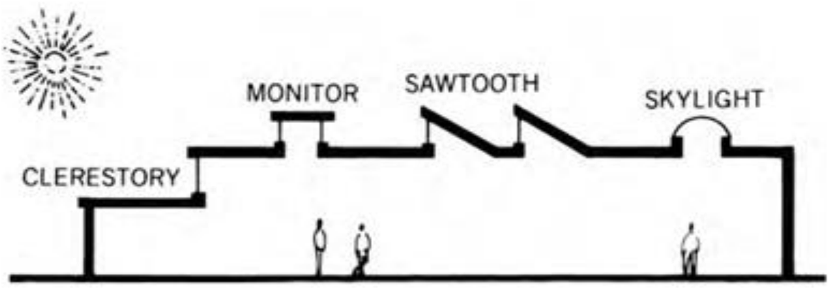

Fig 2:- The various possibilities for overhead openings for daylighting are shown

However, two problems arouse regarding skylights. First, light intensity is greater in the summer than in the winter, which is on the contrary of what is needed. Second, there is a difficulty in shading horizontal glazing. This is why it is more suitable to use vertical glazing on the roof in the form of sawtooth arrangements, monitors, or clerestory window as seen in (Fig2.) [9].

C. Types of Top Lighting Technique

Daylighting is also characterized by reducing some symptoms, like headaches, seasonal affective disorder, eyestrain, and lower fatigue. Daylighting also improves the mood in general. Besides the advantages of top lighting, it also helps the designer to assign a better choice of source placement that gives more uniform illumination from the sky, as well as improving security and privacy.

➢ *Direct Top Lighting*

It was horizontal or slightly sloped glazed openings in the roof. Being in such position enables to uncover a large part of the unobstructed sky. Therefore, very high levels of illumination can be transmitted. Knowing that direct sunlight beams is unwanted for the difficulty they cause in visual tasks, then entering sunlight must be diffused in some manner. Unlike windows, skylights translucent glazing can be handled as direct glare can be avoided on a large scale, meanwhile there is no view to be blocked [9].

➢ *Indirect top lighting*

Indirect top lighting takes a vertical position with vertical glazed aperture situated above the ceiling facing the horizon, allowing daylight to penetrate and reflect down. This allows light to enter into the center of a space. such as monitors, sawtooth and light scoops [9].

- *Indirect lighting has advantages:-*
  - ✓ Prevent direct sunlight penetration into the space.
  - ✓ Provide gentle, uniform light throughout the space.
  - ✓ Avoid creating sources of glare.

- *This is provided by:-*
  - ✓ Allow occupants to control the daylight with operable louvers or blinds.
  - ✓ Design the electric lighting system to complement the daylighting design and encourage maximum energy savings through the use of lighting controls [10].

D. Types of Top Lighting Shading Techniques.

With the exposure of top lighting to diffuse skylight and direct sunlight, the occurrence of glare becomes higher. This is why using other techniques for controlling the indecent light on top lighting aperture is needed.

In order to enhancing daylighting performance should be avoid glare, diffuse light, and prevent puddles of sunlight, top lighting whenever possible and louvers or baffles are advisable to be used. And following this is guideline: -

- ✓ Instead of using overhangs to block the low east and west sun, roller shades or outdoor venetian blinds can be used. They can be used along with the overhangs or instead of it.
- ✓ Use shading systems like internal louver and external louver for diffuse the sunlight and test it by the simulation program.

Table 1. Shows the values for common indoor shading devices, such as curtains and shades. The table also gives values for the shading performance of various glazing systems. It can be observed from the table that the SHGC is very good for describing shading view and privacy. Yet, daylighting can be obtained while still shading the sun. [9].

Device	SC
Interior shading	
Venetian blinds	0.4-0.7
Roller shades	0.2-0.6
Curtains	0.4-0.8
External shading	
Eggcrate	0.1-0.3
Horizontal overhang	0.1-0.6
Vertical fins	0.1-0.7
Trees	0.2-0.7

Table 1:- Shading Coefficients (SC) and Solar Heat Gain Coefficients (SHGC) for Various Shading Devices.

III. OBJECTIVES

The goal of this paper is to improve the performance of daylighting levels into a deep interior space (draw studio) by using top lighting techniques with shading systems to reach the required visual comfort.

IV. PROBLEM STATEMENT

Universities in Egypt was built with spaces characterized by large depth to allow the exercise of functions required courses that need large areas such as draw studios relevant Engineering faculty; those spaces are not reaching the minimum requirements to provide a good educational environment as environmental criteria,

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sustainability, and green requirements as well as efficient energy.

The main objective of the design of a good educational environment is to provide the main criteria for the composition of this environment and the most important visual comfort through Daylighting with regular distribution while avoiding problems resulting from an imbalance in the distribution, such as glare phenomenon or darkness.

V. METHODOLOGY

The Simulation consisted of two phases. The first phase investigated the effect of changing the central top lighting opening ratio from the total ceiling area and angle of sawtooth inclination on daylighting performance.

The second phase investigated the effect of different shading techniques to treatment annual sunlight exposure and enhancing daylighting performance for sawtooth system.

VI. DAYLIGHTING METRIC

Daylighting performance metrics are set into two kinds: the dynamic daylight performance metrics; which consider the quantity and character of seasonal and daily daylight variations for a given building site as an alternative to the daylight factor-based approaches , and the static daylight performance metrics; such as the daylight factor[11].

Illuminating Engineering Society (IES) approved method for daylight metrics is highlighted in this research. It is classified into Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE), where both utilize the same building information and simulation methodology, which are used in analyzing the hourly illumination patterns summed for an annual period across an analysis area [IES-The Daylight Metrics Committee, (2012)(.The research also shed light on one of glare measurements; which is daylight glare probability

A. ASE (Annual Sunlight Exposure).

Annual Sunlight Exposure (ASE) is defined as a metric that describes the potential for visual discomfort in interior work environments. It is the percentage of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year; accepted:- ASE (annual sunlight exposure) % area > 250 hour per year, 1000 lux the ASE 10% threshold criteria adopted by LEED seems restrictive [12].

B. sDA (Spatial DayLight Autonomy)

Spatial Daylight Autonomy (sDA) is defined as a Metric that describes annual sufficiency of ambient daylight levels in interior environments. It is the percentage of an analysis area (the area where calculations are performed - typically across an entire space) that meets a minimum daylight illuminance level for a specified fraction of the operating hours per year.

Moreover, it was demonstrated through annual computer simulations that spatial daylightautonomy300/50% (sDA300/50%) of at least 55%, 75%, or 90% is obtained by using regularly occupied floor area [13].

C. Analysis Software Simulation Tool

Rhinoceros v5.5, Diva-for-Rhinov.4. (plugin software and Grasshopper plugin for Rhinoceros) were used in carrying out the analysis to interface Radiance and Daysim. Evalglare was used for analyzing Radiance based fish-eye renderings of glare situations using the DGP (Daylight Glare Probability).

D. Weather Data File

The baseline case for the drawing studio was chosen to be in the city of Alexandria, Egypt (in 31°N and 29E), which has a sunny clear sky. The utilized weather data file was Alexandria ETMY weather file. [14].

E. Occupancy Schedule

The occupancy schedule was identified to range from 8:00 AM to 6:00 PM (the period of occupancy in daylight.

Fig 3:- View of the Drawing Studio

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F. Working Plane

The working plane was selected at 0.90 m height from the floor. The selected analysis grid in this study was divided by 60 x 60 cm above the finish floor level, which resulted in 737 measuring points.

VII. SIMULATION ANALYSIS

A. Base Case

The case study is carried out in Alexandria, Egypt, where it serves as a drawing studio in faculty of engineering at the University of Alexandria as shown in (*Fig.*3). It is a rectangular shape with height 4m, width 10.60m, and length 24.50m, The area of the studio is 260 m2, as shown in (*Fig.*4)it has three windows on each side, it's a total area of 32.80m2. It was located for latitude, longitude at 31°12′26″N and 29°55′27″E; its ceiling is a rectangular shape has a flat slab for the structural system; Its material is as shown in table 2.

Material name	Material color	Material type	Reflectivity
Wall	Yellow	Opaque	70%.
Floor	Gray	Opaque	20%.
Ceiling	White	Opaque	80%
Window	void glass Glazing _Single Pane -VT: 88%		

TABLE 2: material of internal surfaces for base case

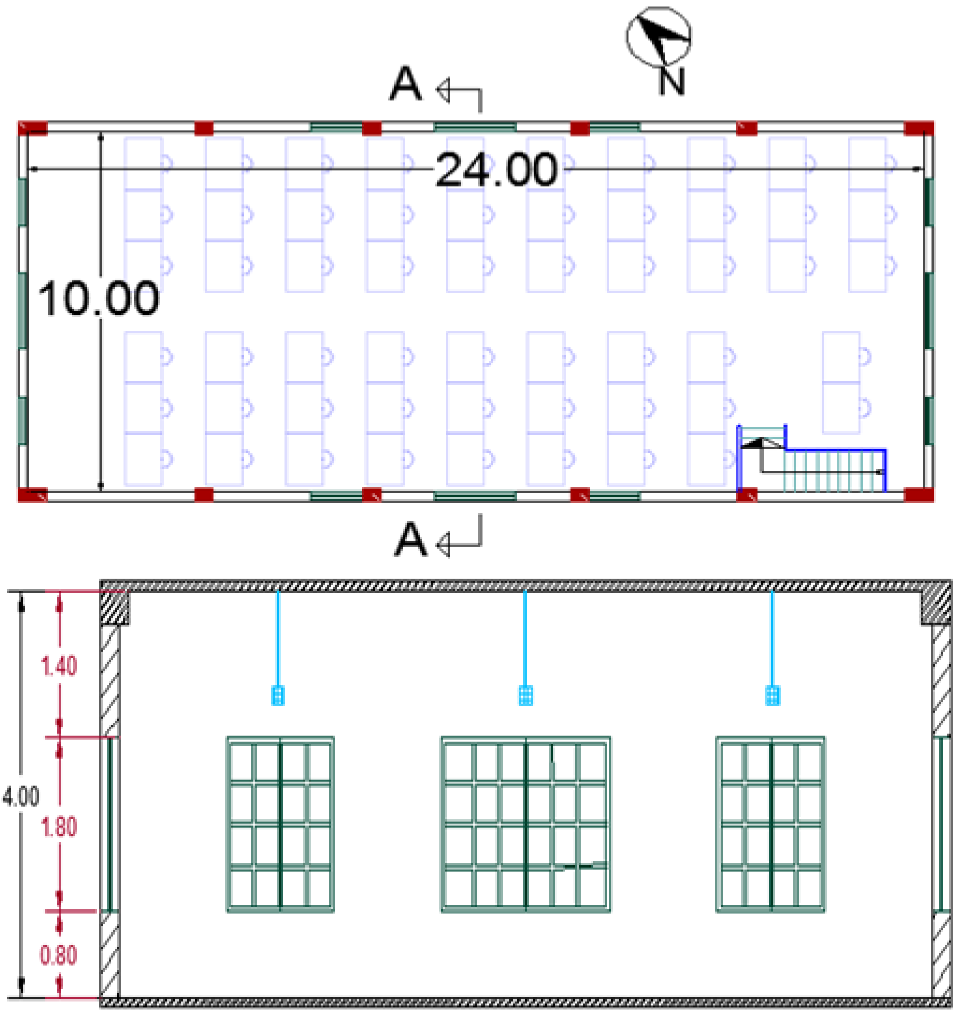


Fig. 4:- Plan and sections showing the architectural Parameters of the "Base Case"

B. Base Case Results(sDA-ASE-DF)

The results of the ASE, sDA & DF for the Base Case. Although the DF shows that the investigated space is 2.71%, the sDA shows that space is 64.2% "daylit"; and it was < 75% According to IES-The Daylight Metrics Committee (2012) so it has not preferred for accepted criteria daylighting. Meanwhile, the ASE was 21.3%, which means that the investigated space was found to be exposed to more than 1000 lux of direct sunlight for more than 250 hours per year. According to IES-The Daylight Metrics Committee (2012), daylight spaces that were predicted to have more than 10% ASE1000, 250h was judged to have unsatisfactory visual comfort. Consequently, the DGP was investigated. [15]

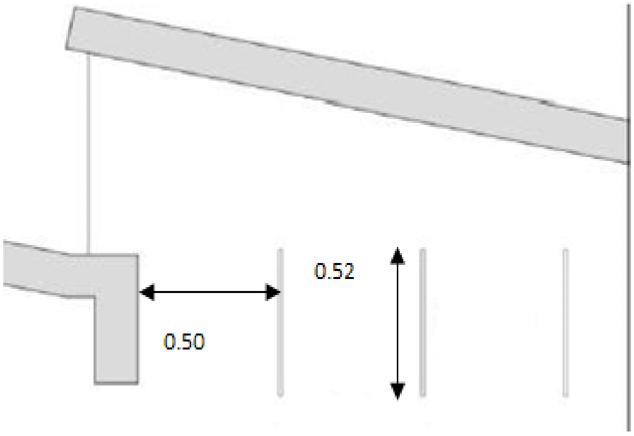


Fig 5:- Internal Louver Shape

C. Design Variants and 3D Parametric Models.

Different design variants were determined and established by parametric modeling. The design has two changing values. These are the central top lighting opening ratio from the total ceiling area and angle of sawtooth inclination.

First phase: The area of central top lighting opening ratio to roof area ratio are 10%,15%,20%,25%,30%,35%, 40%,45%, 50%,55%,60%,65%,70% (table 3.7). In this way, construction cost is saved and daylight from the side windows is used to enhance levels of the lighting of internal spaces.

Second Phase :The input parameters of the model identified the latitude and surface dimensions of the site of the roof, the orientation and the height of the apertures, the angles of saw-tooth inclination), leading to an angle of sawtooth inclination of 60,65,70, and75 degrees. (table 4).

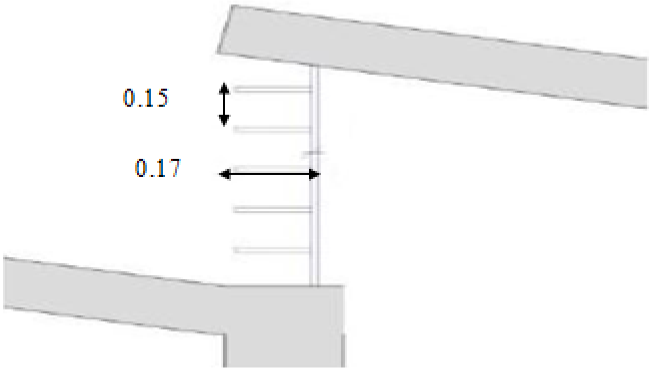


Fig 6:- External Louver Shape

Third phase: analyze how shading techniques, affect daylighting performance the cases starting Spatial Daylight Autonomy from 90 % were selected. By using two types of shading techniques that have many parameters and design variants were chosen, namely: internal louvers or baffles and external louvers. There are two rotation angles of louvers (vertical for internal louver, horizontal for external louver and rotated 45 degrees for each one). To reduce Annual Sunlight Exposure (ASE) see (Fig.5) and (Fig.6).

The final phase : the shading system will be used to the side windows located in south orientation to reduce direct sunlight to the selected condition in which it is investigated accepted criteria at the angle of louver inclination (degree) 60,65,70,75,80,85 and 90 at each orientation.

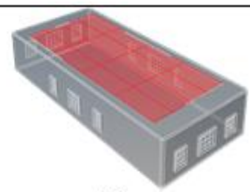
from 10% to 70%	
 10%	 70%

TABLE 3:- The Area of Central Top Lighting Opening Ratio to Roof Area Ratio.

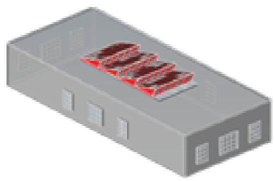
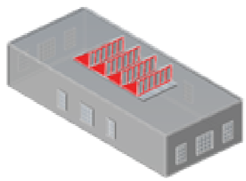
From 60 to 75 (degree)	
 60degrees	 70 degrees

TABLE 4:- The Angle of Sawtooth Inclination (Degree)

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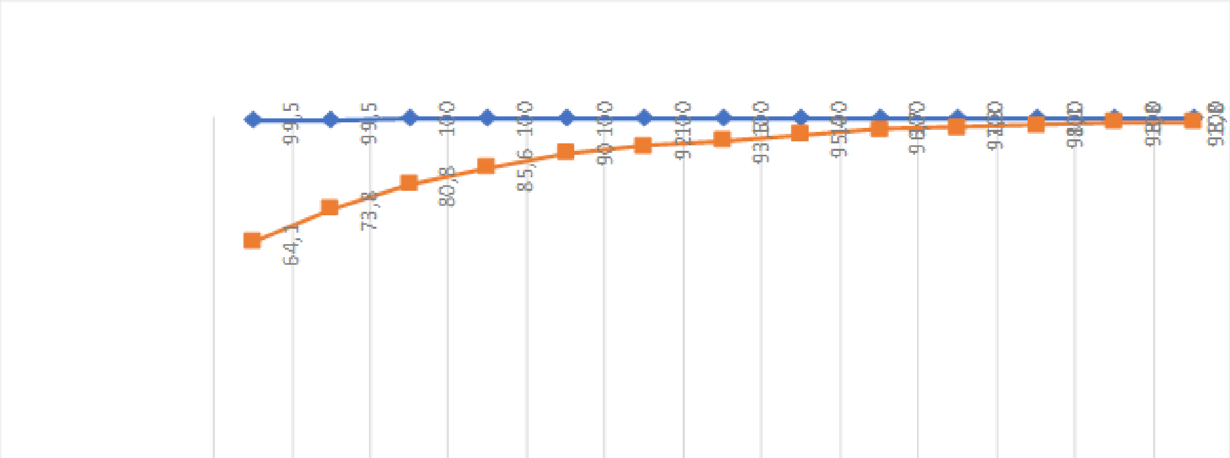
VIII. RESULT OF SIMULATION ANALYSIS

First phase result: After reviewing the results obtained from the (Fig.7).it was found that the independence of spatial daylight and annual exposure to sunlight do not meet the standards of IES (Society of Lighting Engineering)whereas results sDA achieved the preferred case but ASE results more than 10%. For this reason, the sawtooth will be used for the area of central top lighting opening ratio to reduce direct sunlight to the selected condition in which it is investigated.

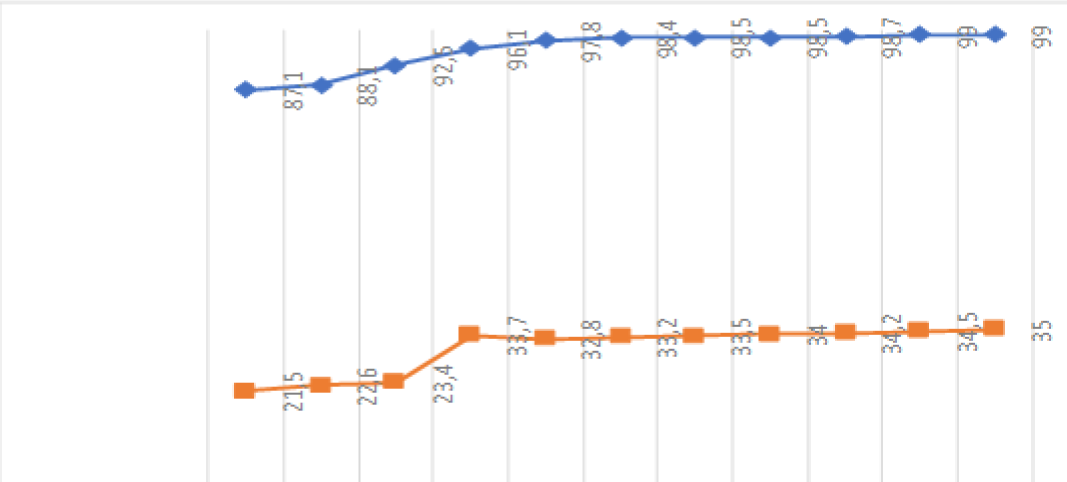


	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
sDA	99,5	99,5	100	100	100	100	100	100	100	100	100	100	100
ASE	64,1	73,8	80,8	85,6	90	92	93,5	95,4	96,7	97,3	98,1	98,8	98,8

Fig.7:- The Area of Central Top Lighting Opening Ratio

Second phase result :As shown according to the previous pictures, after making a comparison between the results of each of ASE and sDA .It was found that starting from the rate of the central opening aperture, 20% of the internal lighting reaches the highest level, but the annual radiation resembles the required limit, so the sawtooth will be used to reduce the radiation percentage.

The results of simulations for a case with a 75-degree angle to the northeast and northwest , it was found that all cases achieve the required level of optimum performance for sda , and the annual solar exposure has closet to base case than case with angle 70 ,65and 60 degree but unacceptable for criteria IES ; (Fig.8)and (Fig.9)



	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
sDA	87,1	88,1	92,5	96,1	97,8	98,4	98,5	98,5	98,7	99	99
ASE	21,5	22,6	23,4	33,7	32,8	33,2	33,5	34	34,2	34,5	35

Fig.8. North East at angle 75°

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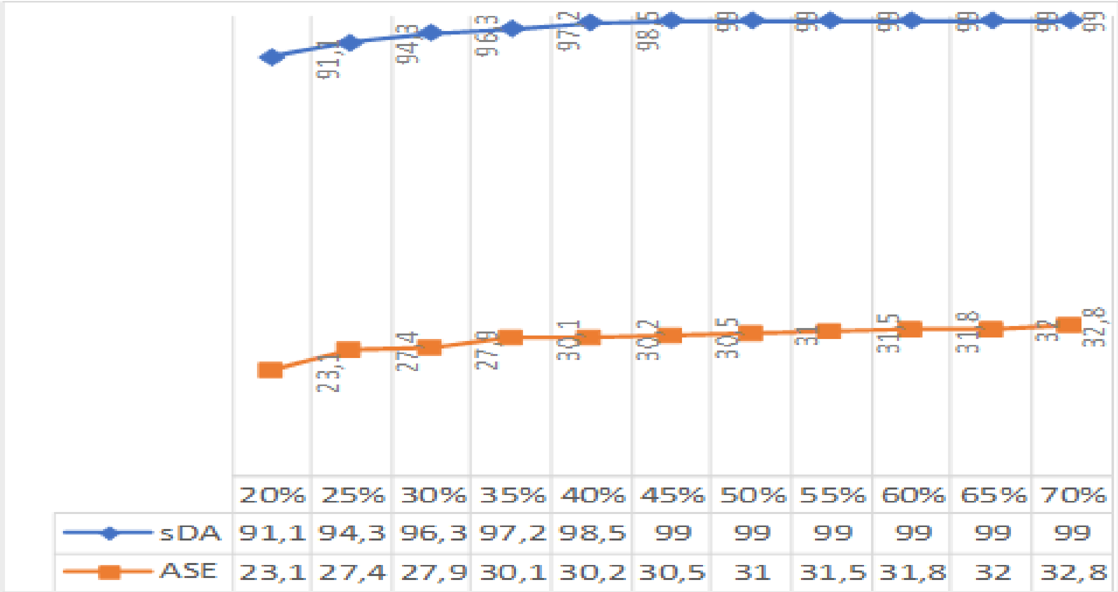
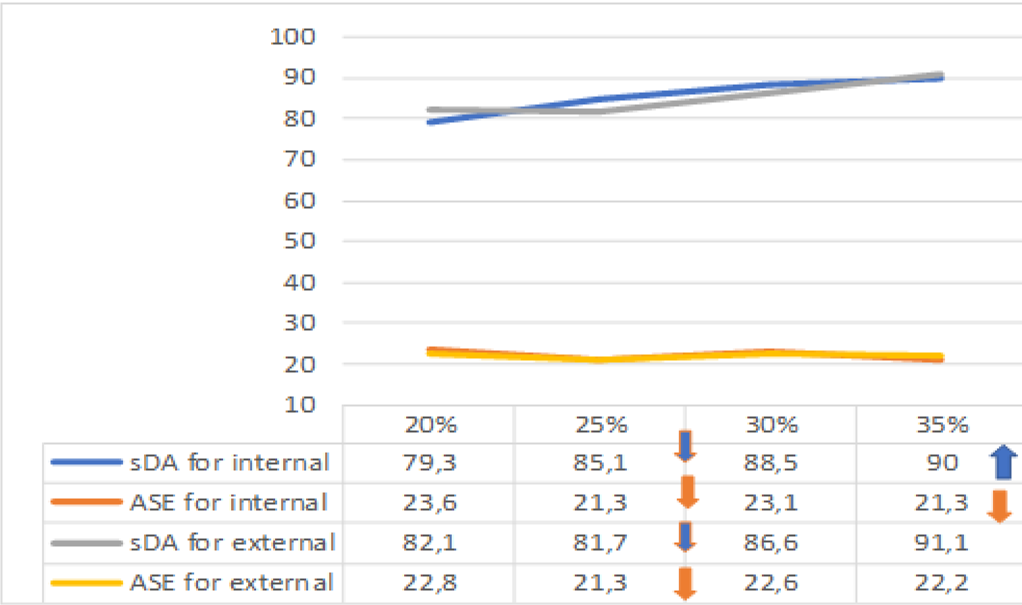


	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
sDA	91,1	94,3	96,3	97,2	98,5	99	99	99	99	99	99
ASE	23,1	27,4	27,9	30,1	30,2	30,5	31	31,5	31,8	32	32,8

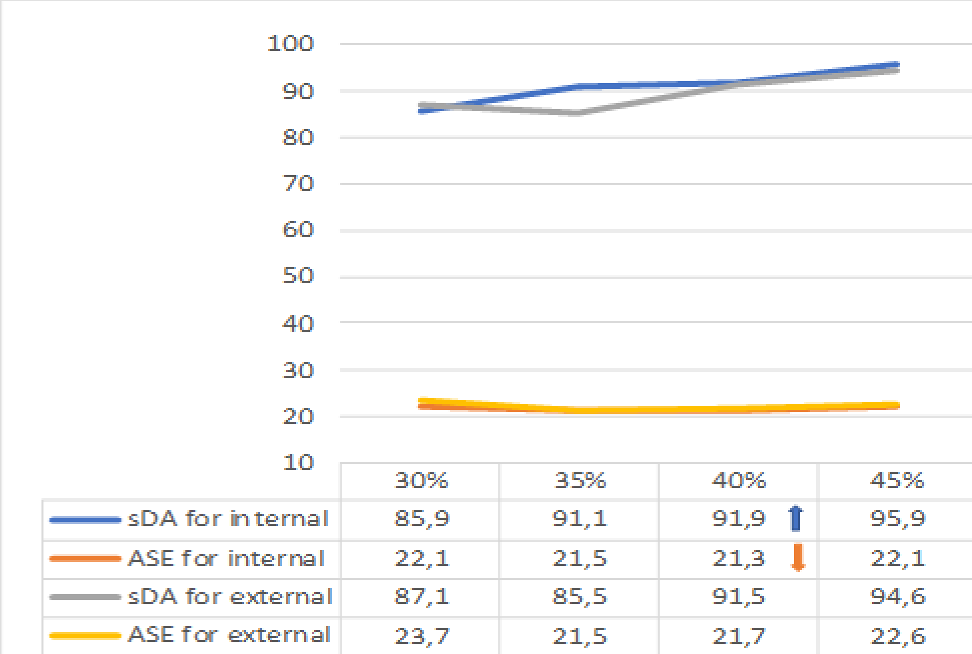
Fig.9 .North West at Angle 75º



	20%	25%	30%	35%
sDA for internal	79,3	85,1	88,5	90
ASE for internal	23,6	21,3	23,1	21,3
sDA for external	82,1	81,7	86,6	91,1
ASE for external	22,8	21,3	22,6	22,2

Fig. 10:- The Internal and External Louver North West at Angle 0o (Horizontal) &90 º(Vertical)

Third phase result: Third phase : the graph in (Fig.10)show the result for ASE at external louvers and ASE result at internal louver were Close together and achieved the less result but sDA at internal louver less than result sDA at internal louver and not achieved to the preferred level.

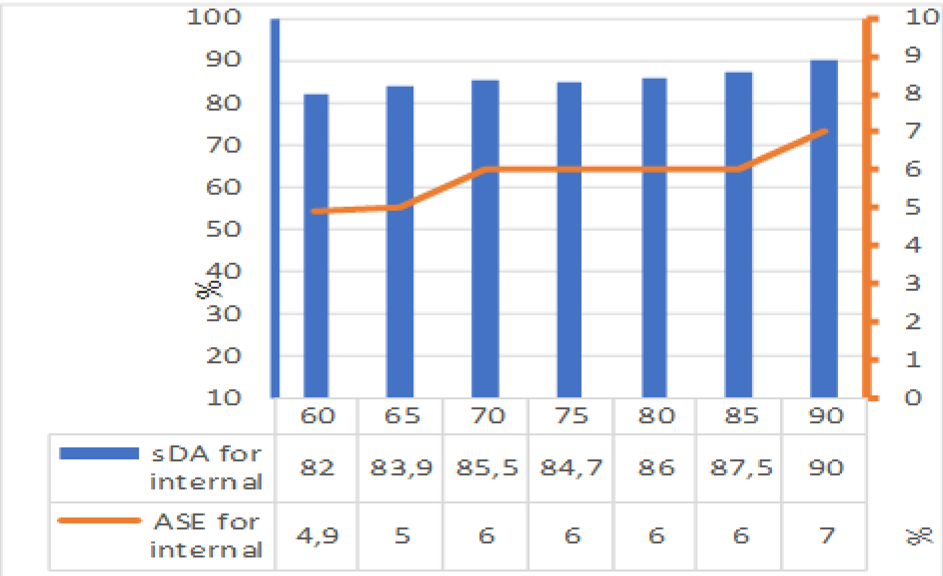


	30%	35%	40%	45%
sDA for internal	85,9	91,1	91,9	95,9
ASE for internal	22,1	21,5	21,3	22,1
sDA for external	87,1	85,5	91,5	94,6
ASE for external	23,7	21,5	21,7	22,6

Fig.11:- The Internal and External Louver North East at Angle 0o (Horizontal) &90◦(Vertical)

(Fig.11)show A comparison between results for ASE In the case with internal louver for sawtooth and ASE In the same case but with external louver for saw tooth found the result ASE for the case with internal louver was closet to ASE for the base case and the sDA result for the same case achieved to the preferred level. When comparing it with the same case (internal louver at a vertical angle) but at the northwest, found the case at northeast has the result for sDA and ASE better than the case with internal louver at a vertical angle in northwest orientation.

The final phase Treatment the chosen case for each orientation: after reviewing the results obtained from previously for internal and external found the less value was 21.3 %; this result the same result for base case(the current situation); so the shading system will be used to the side windows located in south orientation to reduce direct sunlight to the selected condition(the case1 has sawtooth and internal louver for northeast at angle 90◦(vertical) with 40% central opening from total ceiling area and the case2 has sawtooth and internal louver for northwest at angle 90◦ (vertical) with 35% central opening from total ceiling area in which it is investigated accepted criteria at the angle of louver inclination (degree) 60,65,70,75,80,85 and 90 at each orientation see (Fig.12) and (Fig.13)



	60	65	70	75	80	85	90
sDA for internal	82	83,9	85,5	84,7	86	87,5	90
ASE for internal	4,9	5	6	6	6	6	7

Fig.12:- Internal Louver North East at Angle 90◦(Vertical)

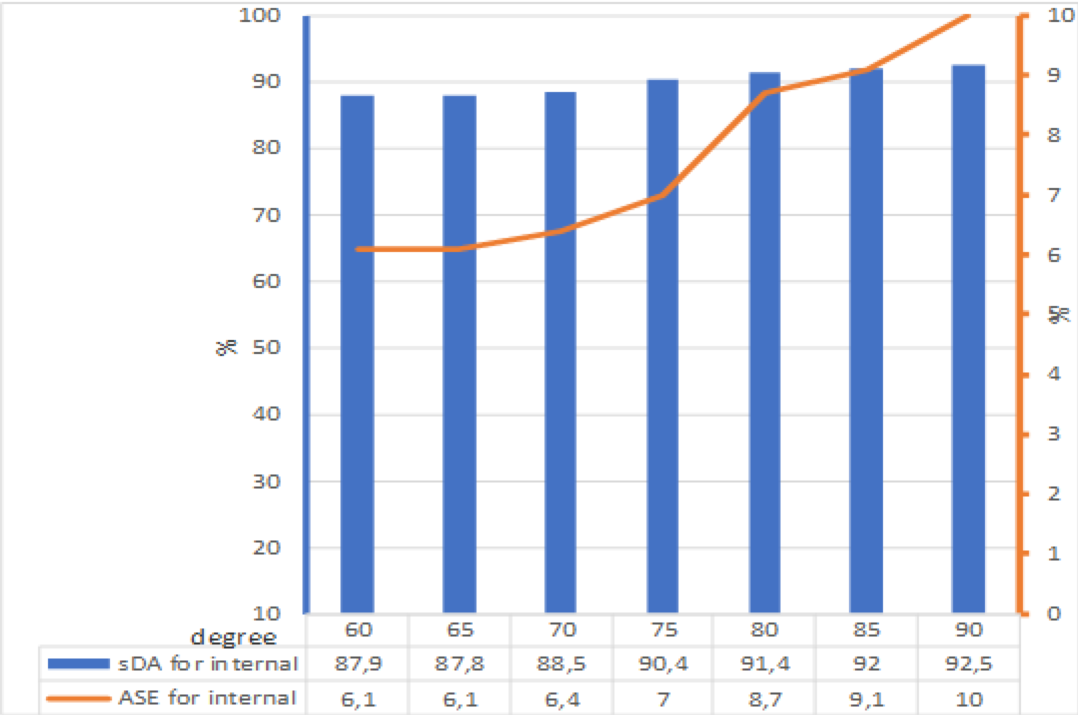


Fig.13:- The Internal Louver North West at Angle 90°(vertical)

IX. CONCLUSIONS

The research included a methodology for integrating computational methods and performance simulation tools such as rhinoceroses, grasshopper and diva for rhino to ensure its ability to provide performative solutions at the early design stages. The presented methodology can be applied in other cases with different characteristics to obtain efficient daylighting performance in buildings. The findings of this thesis highlighted the importance of using performance simulation tools in design as each technique was found to perform differently according to its parameters. Considering and testing these parameters makes a real difference in the overall performance. Finally, the results showed the promising potential of using computational methods along with simulation tools. It paves the way for more research in the area of building performance and its relation with the design of the building.

After analyzing all the results for the simulations found that: the best solutions for the current situation to improve the internal lighting and Reduce the annual sun exposure to reach them to the acceptable level according to the acceptance criteria for IES as shown in the table 5.

In northeast and northwest orientation, Four cases for each orientation with a different ratio for the area for the central top lighting opening to a total area of the roof and the Angle for sawtooth inclination were accepted and achieved to acquire accepted result for sDA nearly from 90 % to 99% of daylit areas for more study in this research. By using shading techniques to reduced sunlight exposure were integrated with internal louvers which enhance daylighting performance inside the space to choose the best case for each orientation was achieved to accepted criteria for spatial daylight autonomy result without any increase at annual sunlight exposure.

Orientation	Base case	North East	North West
Angle for sawtooth inclination		75O	75O
Ratio of central opening in celling		40%	35%
Angle for internal shading system for sawtooth		(vertical)	(vertical)
Angle for blind to southside window		90^{O} (horizontal)	75^{O}
ASE	21.3%	7%	7%
sDA	64.2%	90%	90.4%

TABLE 5: the results for treatment for annual sunlight exposure and spatial day light autonomy

X. RECOMMENDATIONS / FUTURE RESEARCH WORK

The results showed many varieties in the design of sawtooth with high daylighting performance. Sawtooth roofs are recommended to be directed in the northeast or northwest orientation.

The research can be extended in several ways as follows:

- The results of this research can be investigated in different geographical locations.
- The results of this research can be investigated and compared its performance for other environmental aspects such as: Energy consumption, Thermal comfort, Natural ventilation.
- daylighting levels can be enhanced in buildings already built by following the methodology used to upgrade lighting levels within educational spaces
- Moreover, investigating the use of dynamic shading techniques for more adaptive solutions and comparing the feasibility of dynamic techniques and fixed techniques may give a better guide for designing a better visual environment of drawing studio with even daylighting distribution.
- combining shading techniques with different top lighting strategies can be an interesting field to study.
- Finally, verification of the results of this study by real-life measurements can strengthen the thesis recommendations.

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ACRONYMS

ASE: Annual Sunlight Exposure.
sDA: Spatial Day Light Autonomy.
DF: Day Light Factor
IES: Illuminating Engineering Society.

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