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Daylighting Retrofitting in Existing Educational Spaces

(By using Solar Tube)

"A Case Study of Design Studio Hall in Cairo, Egypt"

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Abstract :Recently, many researchers have been interested in designing the buildings to get the benefit from daylight inside, which saves a lot of building consumption for artificial lighting, which gives visual and thermal comfort and also contributes to reducing costs.

But a few of them were interested in how to modify the designs of the existing educational spaces that did not reach daylight, which increases the consumption of these spaces for industrial lighting and gives a lack of a sense of visual and thermal comfort, and that is inconsistent with the principles of designing educational spaces that aim to reach the maximum visual comfort for the student, which helps in raising the performance of the student during the educational process.

Therefore, this research will cover possible retrofits of daylight with existing educational spaces using modern daylight techniques to reach the visual comfort which students need.

Keywords: Innovative day lighting systems, Retrofitting, Educational Spaces, Solar Tube, Spatial day lighting Autonomy (sDA).

1. Introduction

But now with the development of global warming, it is important to try to replace the electrical energy consumed in artificial lighting with daylight, which reduces lighting consumption (and cooling), but also effectively reduces peak electrical loads. And through the current development in technology, many of the systems have been developed, as the efficiency of the system has increased significantly. Furthermore, during the summer months, it can be difficult to reduce solar gains and achieve adequate daylight levels, leading to a trend to improve facade designs to meet both needs. This is done by many methods, such as improving shading systems (such as blinds, rollers, etc.), which reduces the supply of daylight.

During the past periods, bringing usable daylight deep into the core of the building or in areas that are not lit by day has become one of the most important challenges, which could lead to significant savings in energy consumption while creating an attractive visual environment. Conventional window systems can provide sufficient daylight in areas near building openings (the perimeter). The increase in this area can be achieved either by using a design strategy with respect to a different building form (i.e with an atrium) or a system that provides specialized spectral selectivity and/or angle. The latter can be called a daylight system in the sense that it can extend performance far beyond conventional solutions [2]..

2. Objectives

The objective of this paper is to examine how to enhance the daylighting performance in case of an existing educational space located in Cairo, Egypt. The paper shows the effect of adding Innovative daylighting technique (Solar Tube) to provides a better performance.

3. Research Problem

According to the Illuminating Engineering Society of North America (IESNA) and European Standards (CEN) demonstrating the right amount of lighting and daylighting for spaces, the amount of daylight available within spaces affects users' performance significantly. Deep spaces can cause visual problems that need to be addressed and that contain little daylight. This negatively affects the performance of users.

4. Research hypothesis

The Innovative daylighting technique (solar tube) can improve the daylighting in an existing educational space. Moreover, simulation tools can be used to predict the performance of the proposed solution to prove this technique will be affected in this place.

5. Methodology

Computer simulation is used to evaluate the performance of the suggested passive daylighting techniques. Rhinoceros is used to build up the model. Thus, the first stage is using Climate Studio, a plug-in to Rhinoceros, to simulate the illuminance level. [3] The following cases of innovative daylight techniques were suggested to improve the visual comfort in the classrooms.

6. Daylight and productivity

Researchers argue that lighting has no effect on the mood and performance of users. For example, most people who live in uncomfortable buildings escape from those buildings in search of more comfortable places, and it has been found that being in those uncomfortable places can lead to disease or slow down the breakdown of biological function. It was found that one of the reasons that affect people's flight is the lack of natural sunlight entering the place where they live. Therefore, the controversy was resolved that the human body desires to enjoy good health, and in order for a person to enjoy a very great physical and mental strength, it is necessary to have an appropriate environment for that. Every cell in the human body is able to sense and respond correctly to both positive and negative influences in environments [4].

It was also found that, people have the skills in their bodies to know when a place is comfort or uncomforted for them. As a result, Activation, arousal, and stress are three mental reactions that consider to lighting [4].

When the presence of daylight, the glare is influenced by the time-varying luminance distribution of the sky dome and of the interior surfaces, which may change significantly, and so does the glare perceived at different positions and view directions within the same room [5].

7.Lighting Codes for Classrooms

It has been mentioned that the lighting in the classrooms should be appropriate for the activities carried out by the students. [6] Also found that each state has its own lighting codes for classrooms, but all in the range of 300-500 lux. This is according to the Illuminating Engineering Society of North America (IESNA) and European Standards (CEN). Both recommend lighting illuminance levels must not fall below 500 Lux, and it will be reached to 750 Lux illumination in art rooms [7].

7.1 Spatial daylight autonomy (sDA)

We can define sDA as “the percent of an analysis area0 that meets a minimum daylight illuminance level for a specified fraction of the operating hours per year”, that’s to describe the annual sufficiency of daylight levels in interior environments [8].

The sDA value between 55% and 75% indicates a space in which daylighting is “nominally accepted” by occupants. So, Architects or lighting designers should therefore aim to achieve these values of sDA [9].

7. 2 Annual sunlight exposure (ASE)

We can define “the percent of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year”, that’s to describes the potential for visual discomfort in interior work environments. According to IES-The Daylight Metrics Committee (2012), daylight spaces it is preferable to be less than 10% $ASE_{1000,250h.}$ [8].

7.3 Daylight glare probability (DGP)

DGP is used to evaluate the visual comfort and glare aspects. In this research the glare is divided into four categories: intolerable glare (DGP ≥ 45%), disturbing glare (45%> DGP ≥ 40%), perceptible glare (40%> DGP ≥ 35%), and imperceptible glare (DGP <35%) [10].

8.The Selection of the Case Study

A sample hall represents the hall of Design Studio was chosen in Architectural Department in the university (see Figure 1). The dimensions of the Hall are 12m long and 37.21m wide (see Figure 2). The height of the classroom is 3.2m, ending with a false ceiling with height 0.95m as shown in section A-A (see Figure 3). The classroom is sidelight with windows
which have the window to wall ratio (WWR) about 31%.

Since the most important attribute of the material for lighting design is the material reflectance; reflectance of various materials used to build up the classroom were measured using a Luxmeter (model: Lutron LX-102), as shown in (see Table 1).

Fig 1: The hall of Design Studio [Researcher].

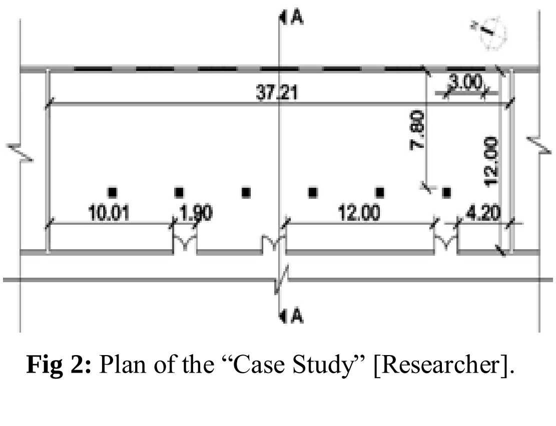

Fig 2: Plan of the "Case Study" [Researcher].

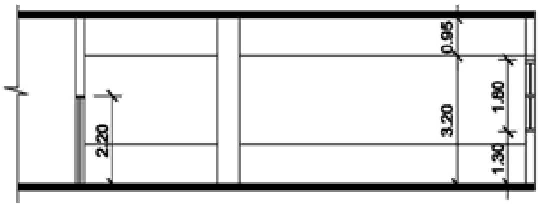

Fig 3: Section of the "Case Study" [Researcher].

Table 1: The Base Case Dimensions and Parameters

Drawing Hall Parameters		
Floor Level	3rd Floor (+13.5m from Zero Level)	
Dimensions	(12m in L) x (37.21m in w) x (3.2m in H)	
Finishing Materials		
Materials & Reflectance	Wall	• Marble Wall 27.9% • Wooden Cladding 16.2% • White Painted Wall 81.2%
	Floor	• Marble Floor 27.9% Tiles (60cm x60cm)
	Ceiling	• White Painted False Ceiling 85.1%
Doors Parameters (3 Doors)		
Dimensions	Width	1.90m
	Lintel	2.20m
Window Parameters (7 Windows)		
Dimensions	Width	3.00m
	Lintel	3.10m
	Sill	1.30m
Glazing Transmittance		87.7%

9 .Explanation and analysis of the simulation study

The occupancy period in this case study as a Design Studio Hall is from 8:00am to 6:00pm. The working plan was taken 75cm above the finish of the floor level. The sensors grid plan contained 1323 points with spacing 0.6m.

10 .The Case Study Results

The sDA result is 51.1% (see Figure 4). ASE is 2.3% (see Figure 5). The avg Lux is 607 (see Figure 6). The DGP is 3.6 % (see Figure 7).

According to the metrics were mentioned before: The sDA value between 55% and 75% and $ASE_{1000,250h}$ less than 10%, the DGP (40%> DGP ≥ 35%). So, we can notice that the sDA is lower than the preferable range and this is the problem that we will solve by using the simulation tool.

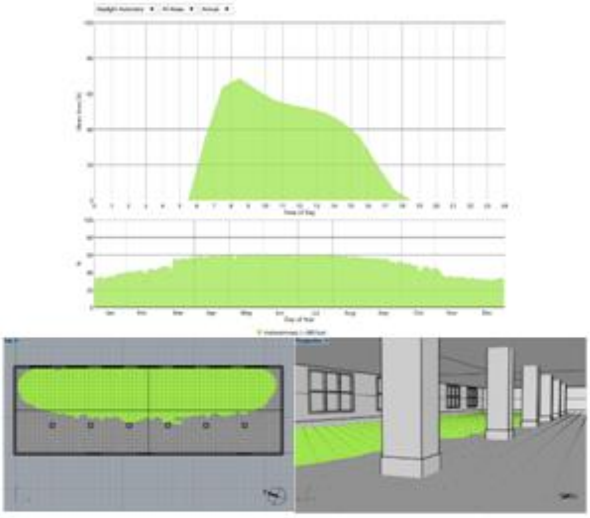

Fig 4: sDA Results for the "Case Study" [Researcher].

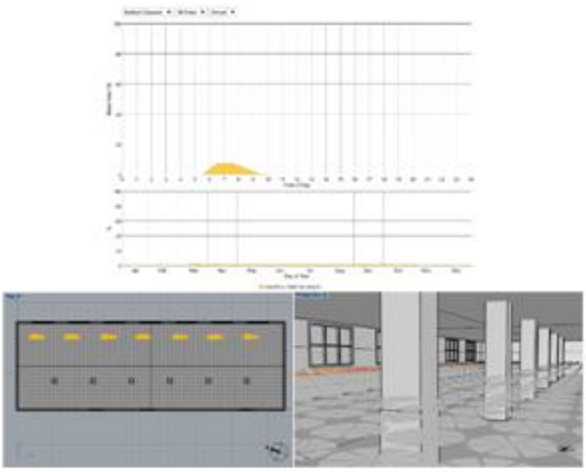

Fig 5: ASE Results for the "Case Study" [Researcher].

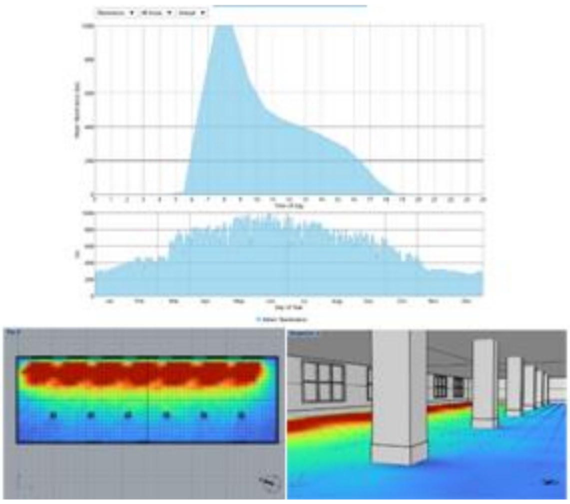

Fig 6: Avg Lux Results for the "Case Study" [Researcher].

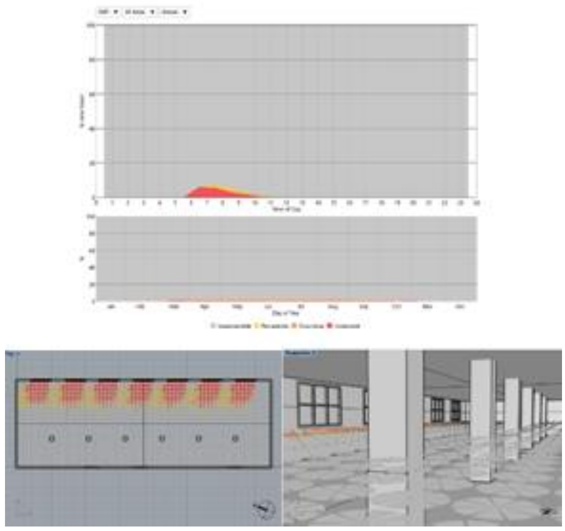

Fig 7: The DGP Results for the "Case Study" [Researcher].

11. Solar Tube

The solar tube is the one of the innovative devices that consists of a pipe, with reflecting material, and an acrylic dome polished aluminum interior and ceiling diffuser. This could be used on the roof of buildings to collect daylight and transport it to the deep spaces with low illuminance and also have no direct accesses to daylight. The light pipe is a very useful system for basement levels and underground building where high illuminance is required to compensate for the low level of daylighting. [11]

11.1 Solar Tube type selection

The simulation tool (Climate Studio) provides several types of solar tube from the site of Solatube [12], this type (Solatube_750DS-O-DAI-L2) is according to the shape and the diffuser size 0.47271 m and VT annual 0.59 (see Figure 8).

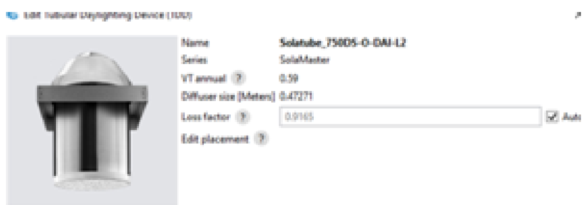

Fig 8: The type of the Solar Tube.

12. Results of the simulation study

The sDA result is 72.9% (see Figure 9), and it is within the preferable range 55% and 75% of sDA. ASE is 2.3% (see Figure 10). The avg Lux is 703 (see Figure 11). The DGP is 6.2 % (see Figure 12).

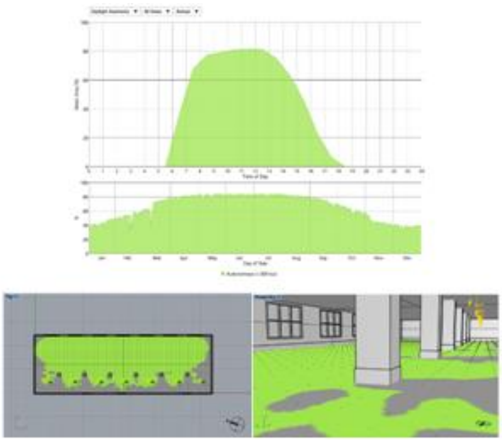

Fig 9: sDA Results for the "Case Study" with Solar Tube [Researcher].

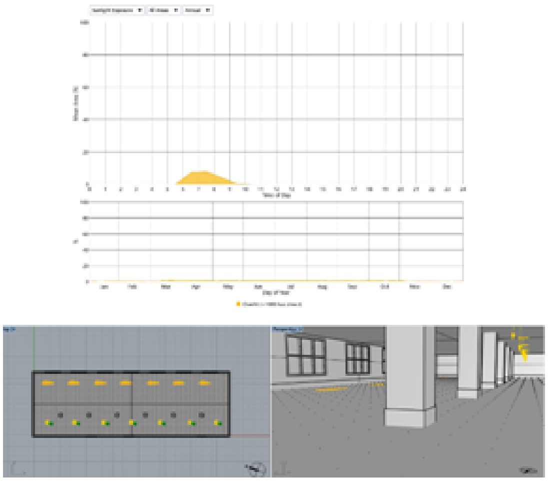

Fig 10: ASE Results for the "Case Study" with Solar Tube [Researcher].

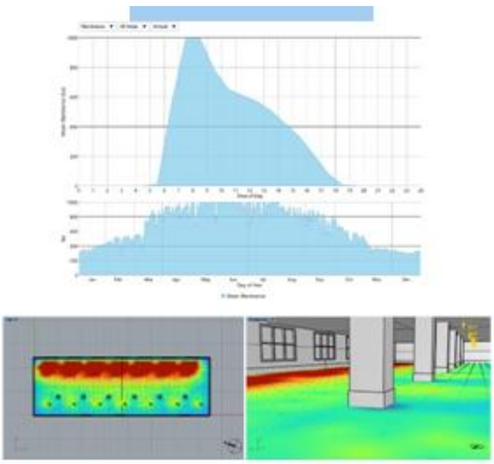

Fig 11: Avg Lux Results for the "Case Study" [Researcher].

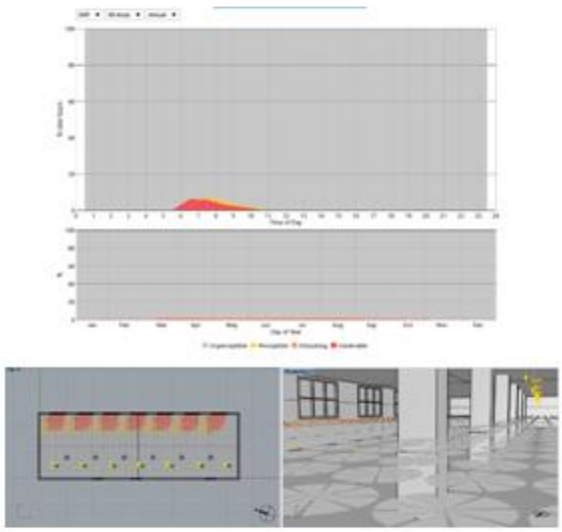

Fig 12: The DGP Results for the "Case Study" [Researcher].

13. Conclusion

In conclusion, by comparing the simulation results of the design studio Space before and after using the solar tube, we find that before, the daylight was insufficient as the sDA result was 51.1% which is below the preferred range (55% and 75%), but with many experiences and after Using 7 devices of solar tube, the SDA result is 72.9% which is in the preferred range. Also, the Avg Lux result rose to an acceptable level, and the ASE results were not affected by anything without negatively affecting the glare.

Therefore, we conclude that the use of the solar tube yielded results close to acceptable levels of SDA and ASE. And the number of solar tube used is determined by experiment and carefully so as not to increase the amount of light significantly, which affects an increase in the intensity of glare and thus negatively affects the users.

14. Recommendations

The paper studied the retrofitting of the existing educational spaces with the solar tube to improve the daylighting performance these spaces. Additional research examining the solar tube with different locations or the other techniques is advised located by the ceiling or the wall

15. References

[1] Mandala, A. (2019). "Lighting Quality in the Architectural Design Studio (Case Study: Architecture Design Studio at Universitas Katolik Parahyangan, Bandung, Indonesia)" ,IOP Conf. Ser. Earth Environ. Sci., vol. 238, no. 1, 2019, doi: 10.1088/1755-1315/238/1/012032.

[2] Tsangrassoulis, A. (2008). "A Review of Innovative Daylighting Systems", Advances in Building Energy Research, 2:1, 33-56, DOI: 10.3763/aber.2008.0202.

[3] Climate Studio for Rhino, [URL: https://www.solemma.com/climatestudio], Last Accessed: July 2021.

[4] Rice, M. (2010). "Biologic Architecture Building Inspired by Nature". Natural Life, 22. Retrieved from https://proquest.umi.com/pqdweb?did=1921724821&Fmt=7&clientId=24792&RQT=309&VName=PQD.

[5] C. Pierson, J. Wienold, M. Bodart. (2018). "Review of factors influencing discomfort glare perception from daylight. Leukos. Epub ahead of print 22 February 2018, https://doi.org/10.1080/15502724.2018.1428617.

[6] Alpin Köknel Yener. (2011). "Daylight analysis in classrooms with solar control". Architectural Science Review 45.4 (2011): 311-316.

[7] Eduardo L. and Dorigo,A. (2008)."Daylighting analysis in a public school in Curitiba", Brazil. Renewable Energy33.7 (2008): 1695–1702.

[8] Illuminating Engineering Society (IES); The Daylight Metrics Committee, (2012). "Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)", p.2.

[9] Baraa J. Al-Khatatbeha, Shouib Nouh Ma'bdeha. (2017). "Improving visual comfort and energy efficiency in existing classrooms using passive daylighting techniques", 4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal

[10] Wienold, J., Christoffersen, J. (2006). "Evaluation Methods and Development of a New Glare Prediction Model for Daylight Environments with the Use of CCD Cameras", P.743–757.

[11] Dr. Mohsen M. Aboulnaga . (2003). "Advanced Daylighting & Lighting Technology For Sustainable Architecture Design" , Submitted as part the promotion requirements for the title of professor in Architecture & Sustainable Design , Department Of Architecture , College Of Engineering , Cairo University , pp. 2-32 .

[12] Solatube, [URL: https://www.solatube.com/commercial/products], Last Accessed: July 2021.