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Design and Analysis of a Passive Lighting Device for a Sustainable Office Environment in Hot-Arid Climate Conditions

Mohamed Yacine Saadi[1*], Safa Daich[1], Ahmed Motie Daiche[2]

[1]Mohamed Khider University of Biskra, Department of architecture, LaCoMoFa Loboratory, Biskra, 07000, ALGERIA

[2]Abderrahmane Mira University, Department of architecture, Bejaia, 06000, ALGERIA

*Corresponding Authors

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Abstract: Visual comfort in office spaces improves not only productivity and wellbeing but also satisfaction and energy efficiency of the buildings. The objective of this research is to study the effect of one of the transporting daylighting systems (Anidolic Integrated Ceiling 'AIC') on the enhancement of the luminous interior environment and energy saving in office building through objective and subjective evaluations. The quantitative study was performed by measurement of the illuminance values in the physical model (1:4) under local luminous climate in two scenarios (with and without 'AIC') and by numerical simulation to calculate the daylight autonomy. The qualitative evaluations were achieved by using a field survey composed of four questions related to pleasantness, level of light and artificial lighting needs. Experimental study shows that the AIC offers high levels of illumination in quantitative terms result in moderate values of Daylight Factor (2% - 4%). Simulation results showed that more than 88% of energy consumption for electrical lighting can be saved. Subjective evaluation results indicate that in the test model (with AIC), 67% of participants felt more pleasant with the luminous environment, 74.19% considered that the level of light is sufficient and only 08 of 31 subjects need to use artificial lighting.

Keywords: Daylighting device, visual comfort, energy saving, numerical simulation, physical model, field survey

1. Introduction

Daylight is a natural resource, inexhaustible and clean. It is, therefore, an essential element of the sustainable architectural design and well-being of space users (Galasiu & Veitch, 2006). Several studies have proved that daylighting has positive physiological and psychological effects, improves the productivity of office workers and human beings (Aries, Veitch, & Newsham, 2010). Providing optimal daylighting in deep office buildings has been regarded as the most important environmental qualities (Arsenault, Hebert, & Dubois, 2012). Daylight in these spaces must be sufficiently large especially in the areas located away from the windows with an appropriate illuminance uniformity (Kontadakis, Tsangrassoulis, Doulos, & Zerefos, 2018). Energy conservation in the office building is an essential issue for achieving a sustainable environment. It has been proved that buildings do consume large amounts of electricity for lighting and thus producing tones of CO_2 (Or, 2002) and the use of daylight can save a significant amount of electricity used in lighting (Konis, 2013). The city of Biskra (case of our study) is situated in the southeast of Algeria (Latitude: 34° 52′ 0″ Nord, Longitude: 5° 45′ 0″ Est). The microclimate of this city is characterized by high temperature, little rainfall, high exterior horizontal illuminance level especially during summer seasons, reached 83000lux in May and by intermediate sky cover

*Corresponding author: yacine.saadi@univ-biskra.dz

conditions which approximate 40.21% (Daich, et al. 2017). In this region, the space architecture layout and local climate conditions have a great impact on the interior daylight conditions. The design strategy adopted mainly is that of cooling reducing, therefore, external exposure of the building's envelope and narrowing openings and windows. In deep office spaces, this design approach has the disadvantage of only effectively illuminating areas that are located near the windows. Consequently, the daylight distribution is not uniform in deep spaces and additional support from artificial lighting will be necessary which led unfortunately to overuse of electricity for lighting especially during hot days. One away to solve this problem is by integrating daylighting systems such as light pipes (Kennedy and O'Rourke, 2015), light shelves (Xue, Mak, & Cheung, 2014) and anidolic systems (Roshan, Kandar, Nikpur, Mohammadi, & Ghasemi, 2013). Besides, previous studies have proven the effectiveness of using transporting daylighting system to increase the Daylight Factor in deep spaces, affect the building's energy balance while improving the visual environment (Warrier &Raphael, 2017). Anidolic Integrated Ceiling (AIC) is one of the transporting daylighting systems that has proven its performance for various climate conditions such as tropical, subtropical, temperate and cold climate, but little research has been done in hot and dry regions (case of our study). The principal objective of the current research is to reveal the effect of an Anidolic Integrated Ceiling on the improvement of the interior daylighting quality and energy saving of the building under typical sky conditions of the city of Biskra especially that this system has not yet been adopted in this region. The efficiency of this device will be evaluated by comparing experiment results (subjective data) with simulation results (objective data). This paper can be useful to get an overview of the AIC performances and user's satisfaction in deep office spaces in daylight conditions at a hot climate under the intermediate sky.

Nomenclature:

$2a$ Width of the exit aperture.
$2a'$ Width of the entrance aperture.
f Focal length of each parabola.
f_{int} Focal length of the interior parabola.
f_{ext} Focal length of the exterior parabola.
L Horizontal length of the two-parabola configuration.
θ Angle formed by the horizontal and the line.
connecting one entry edge with the opposite exit edge
Y Horizontal axis of the system profile.
Z Vertical axis of the system profile.
D_{A300} Daylight autonomy with prescribed by regulations.
I llumination in 300 lx, h/year.
DF Daylight factor, %.

2. Literature Review

A variety of light transport systems have been investigated and proved their performances in many studies. According to these researches, it was found that the light pipes and Anidolic Integrated Ceiling are the most systems used in buildings. The principal function of these systems is to collect and transport sunlight over the building. It consists of three main components: 1) light collection; 2) light transportation, and 3) light distribution (Ayers & Carter, 1995). Since most literature comes from equatorial and tropical climate. These technologies can be applied in regions with sunny sky (Mirkovich, 1993), partly cloudy conditions (Daich, 2019) and for overcast sky (Scartezzini & Courret, 2002). The efficiency of each of these systems in the improvement of the visual comfort and the reduction of energy consumption are compared in Table

Table 1 - Comparison of the light transport systems efficiency

Transporting daylighting systems		**Location**	**Building**	**Luminous efficiency**	**Energy savings**	**Methods**
Anidolic Integrated Ceiling	Wittkopf et al. [23]	Singapore & Sheffield	Office Room	≈300lx	21%-26%	Simulations
	Scartezzini & Courret [27]	Lausanne	Office room	2.5%<DF<14%	-	Experiments & Simulations
	Roshan et al. [18]	Malaysia	Office Room	2%<DF<5%	-	Experimental study
	Binarti & Satwiko [31]	Yogyakarta & Singapore	Test building	DF>3%	-	Simulations & Field measurements
Light pipes or Solar-tube	Kennedy & O'Rourke [14]	Dublin	Deep-plan building	350lx-80lx	-	Experimental analysis
	Canziani et al. [32]	Venice	Classroom	300lx-700lx	120-210kwh/ month	Simulations
	Shin et al. 33	Korea,	Building	250lx-800lx	<30%	Experiments
	Baglivo et al. [25]	Lecce (Italy)	-	3500lx-1000lx	38%-42%	Simulations
	Görgülü & Ekrenb [34]	Istanbul (Kadikoy)	office	350lx	≈30%	Experimental study
	Oakley et al. [35]	-	Workshop,	Reach 1200lx	-	-
	Toledo & Pelegrini [36]	Brazil	office, residential landing Test house	200lx-800lx	10.6 kwh	Experiments
	Marwaee & Carter [37]	UK	Commercial, healthcare or academic buildings	75% of users were working in illuminance values above the range of 300-500lx.	-	Field measurement & Survey

Comparing the performance of the different configurations of Transporting daylighting systems, we can find that there is great potential for energy saving by using these passive technologies. In addition, Table 1 showed that the Anidolic Integrated Ceiling provides moderate values of Daylight Factor comparing with light pipes that give very high values of illuminance, which can cause overheating and glare especially under the climate conditions of Biskra (our case study). In this section, we carried out a literature review on the application of Anidolic integrated ceiling in buildings. The AIC was developed at the (LESO-PB) Laboratory in Switzerland (Courret, 1999). The system is constituted, of an external collector integrated into the upper portion of the facade, followed by a reflective light pipe equipped with two internal Anidolic elements in both extremities. The exit aperture located at the rear part of the ceiling, which redistributes the collected light. Scartezzini and Courret (2002) have studied three different anidolic systems (anidolic ceiling, integrated anidolic system, anidolic solar blinds). The devices have been designed and installed under the clear and overcast sky conditions and monitored in experimental test modules. The result showed that a significant improvement of daylight factors monitored ender the overcast sky conditions compared to a reference facade with double glazing: the daylight factor, measured at the back of a room, increased by 1.7 and higher work plan illuminances were observed for the third system under clear sky conditions. Wittkopt, Yuniarti and Soon in 2006 have estimated the energy savings on electrical lighting of an AIC in the office building for two different locations of Singapore (high sun altitude and high building density) and Sheffield (low sun altitude and moderate building density). The Daylight Autonomy was simulated for the configurations of the office rooms: with and without AIC, using computational simulations. The results show quite similar savings on electrical lighting for both locations, 21% for Singapore and 26% for Sheffield. This investigation has some limitations such as the comparable environment does not exist in reality, as both Singapore and Sheffield have yet to adopt the technology of AIC which makes physical measurement impossible. Even if the AIC is in device (systeme), the comparison between two places with distance apart is very difficult to be carried out instantaneously at two places. Also, the materials available for AIC have the properties of up to 99% reflectance, as compared to the 92% reflectance used in this study. Similary, Binarti and Satwiko (2018) assessed the energy-saving potential for lighting and cooling of Anidolic System and conventional aperture models in the tropics (Yogyakarta and Singapore) by measuring the daylight distribution and level, as well as the solar heat gain, based on EnergyPlus and Radiance simulations. The results showed that the integration of the device in the tropics benefits the daylighting performance (DF≥3% and horizontal distribution (51-0%), but still produces higher solar heat gains (44-437% higher than those of clerestory only).

Page, Scartezzini, Kaempf, and Morel in 2007 have analyzed the performance of two advanced building technologies through the integration of an AIC and an electrochromic glazing in a building facade. In order to, identify the optimal design AIC system; computer simulations of different systems were used. when the AIC installed in an experimental building the thermal and visual performance of the anidolic system coupled to an electrochromic glazing was assessed by the on-site monitoring. The performances results were compared to those obtained by the conventional double-glazing unit installed in an identical neighboring room. Evaluation of user's comfort was achieved by way of a survey involving 30 different subjects. The results of this study showed the possibility of system to controlling the daylight flux entering in buildings and of optimizing its distribution. Unfortunately, the daylight factor obtained by the system is lower than those simulation by the computer simulations and he must be improved. The subjective evaluations using the survey confirmed most observations deduced either from computein this studyr simulations or from monitoring. Roshan, Kandar, Nikpur, Mohammadi, and Ghasemi (2013) have investigated the performance of the Anidolic Daylighting System (ADS) with regards to building orientation in real climatic conditions in Malaysia. For that reason, two scale models were built. The ADS was installed in one of the models and the other one was a reference model. The results showed that the particular daylight system offers a great potential for increasing daylight conditions in deep-plan building, since it seems to perform efficiently in the tropical area especially on south orientation. Other authors such as Daich et al. (2017) proved, through simulations and experiments, that the anidolic ceiling offers a great potential for increasing the illuminance level in deep-plan building in hot regions under intermediate sky conditions and provides a good ambiance result by uniform luminance distribution throughout the room which produces a visual satisfaction. The AIC reduces significantly the probability of glare; it is considered as barely perceptible. From the above literature review, we can suggest that most studies have tested the effectiveness of the anidolic system in tropical, subtropical and cold climates and little researches have done in hot regions under very high exterior illuminance levels. Moreover, the authors, in their investigation, resorted to either numerical simulation or experiments by a physical scale model. Therefore, our research is based on the correlation between the two methods.

3. Anidolic Integrated Ceiling (AIC) Design

Numerous studies showed that the AIC provides great opportunities for energy savings especially in deep office buildings (Linhart & Scartezzini, 2010). In this investigation, the AIC was modeled according to the local daylight climate of the city of Biskra using a reference model developed by Wittkopt, Yuniarti and Soon in 2006 and tested by EPFL Laboratory. To establish and identify the AIC characteristics, we have proposed gradual values of (+) or (-) 5cm (0.05m) to the reference value for each configuration (Fig. 1). The dimensions of the different variables of the twelve models obtained have been calculated using the mathematical model given by Welford and Winston (1989) Eq. (1, 2, 3 and 4). The models were then simulated to determinate the most appropriate configuration. The simulation results are presented in Fig.2.

$$f = a' \times (1 + \sin\theta) \qquad (1)$$

$$a = a'/\sin\theta \qquad (2)$$

$$L = (a' + a) \times \cos\theta \qquad (3)$$

$$\theta = (z \cos\theta + y \sin\theta)\, 2 + 2a' (1 + \sin\theta) 2\, z - 2\, a' \cos\theta - a' 2\, (1 + \sin\theta)\, (3 + \sin\theta) \qquad (4)$$

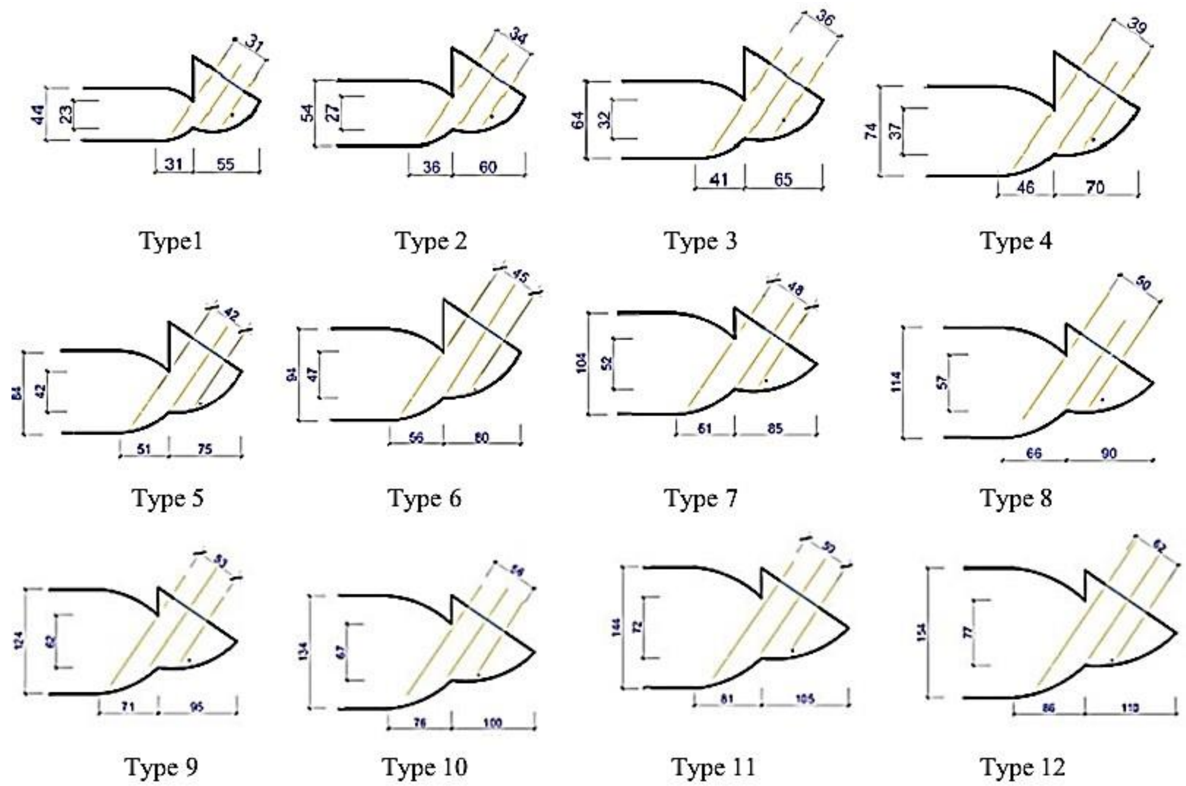

Fig. 1 - AIC models proposed for simulation

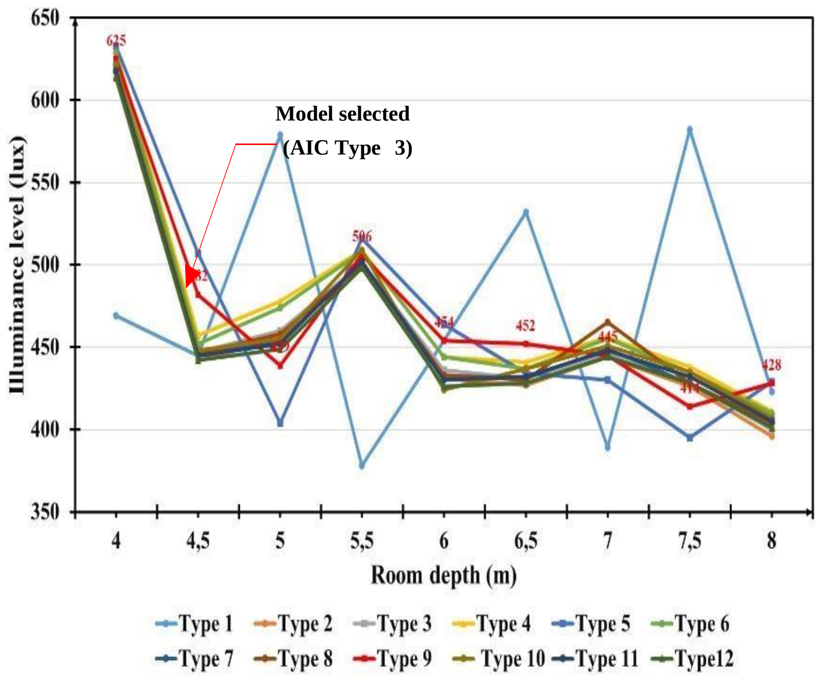

Fig. 2 - Simulation results of the twelve AIC models

Calculations resulting from the numerical simulation showed a very similar trend for the light distribution in the twelve AIC models although there was a slight difference in the level of illumination. It is also observed that AIC 'Type 3'gives good results; the difference between the maximum and minimum illuminance values is the smallest (244 lux), which ensures the homogeneity of the distribution of light throughout the room. In addition, the passive zone, which characterized by illuminance level situated between 300lux and 500lux, covers 83% of the total area of the space. This study clearly shows that the Anidolic Integrated Ceiling ' type 3', which has the following characteristics: a = 0.64m, a` = 0.32m, L = 0.41m, θ = 0.49 °, f int = 0.56m and f_{ext} = 0.46m is the most optimal (Fig. 3.). The results indicate that this configuration improves significantly the level of daylighting, especially at the back of the room where the values are 8 times higher at 9 m from the window.

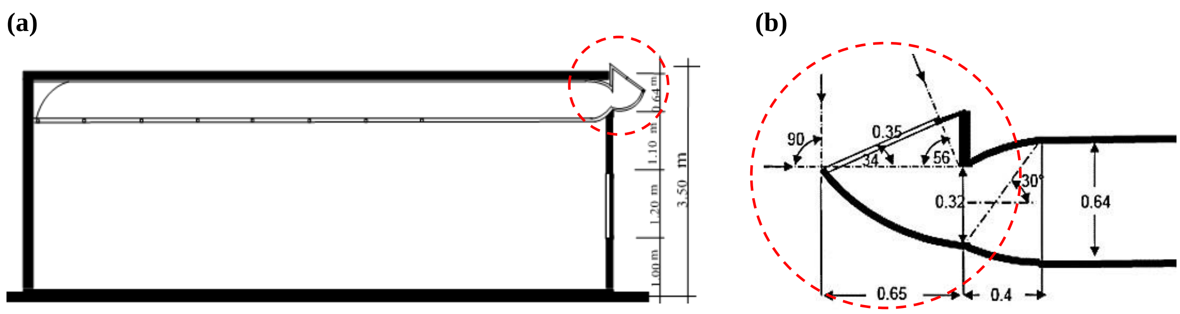

Fig. 3 - (a) Section of the test model; (b) Elevation of AIC with the main dimensions.

4. Methodology

Visual comfort has been commonly studied by using different tools to evaluate the indoor daylighting through a qualitative or quantitative approach or the both such as, Physical scale models (Bodart & Cauwerts, 2017), Field measurements (Moosavi, Norhayati, & Norafida, 2015), Computer modeling & simulation (Indarto, Hardiman, Budi, & Riyanto, 2017) and questionnaire survey (Saadi, 2019). In this section, the procedure of evaluating the anidolic system performance consists of three parts: the first is based on simulations and measurements to assess visual comfort and estimate potential energy-saving when sufficient daylight is provided. The second part is based on a series of questions to collect subjective data about the interior daylight quality. A validation of the results has been proposed in the third part. The methodological steps are shown in Fig. 4. The following subsection describes the experimental protocol, daylight level measurements, survey procedure and simulation process.

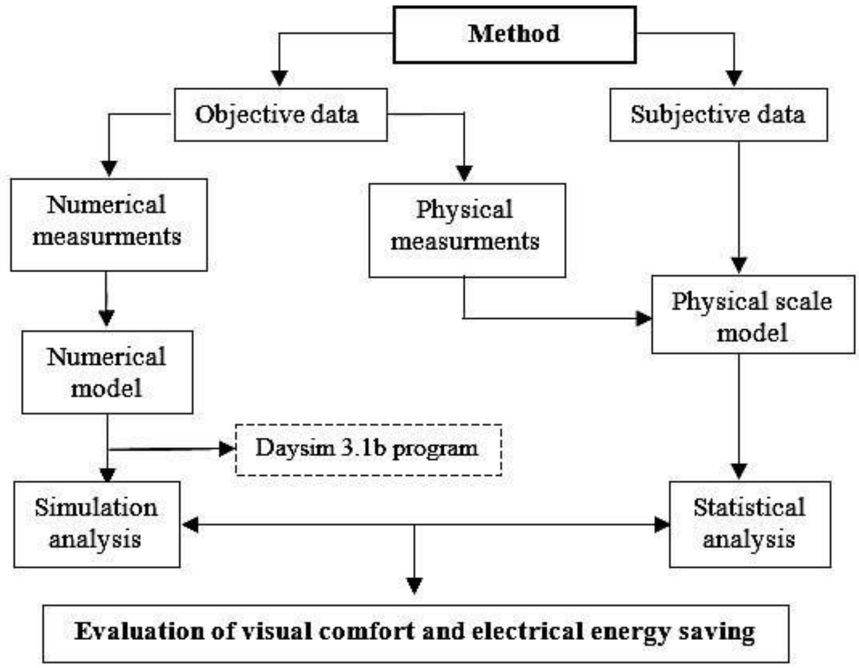

Fig. 4 - Methodological approach

4.1 Experimental Procedure

Results from different studies focusing on assessment of daylighting in buildings have confirmed that the use of physical models is a tool to evaluate the performances of the daylighting systems (Kesten, Fiedler, Thumm, Löffler, & Eicker, 2012). It can provide quantitative and qualitative measurements (Bodart & Cauwerts, 2017). For this, a physical model with a scale of 1:4 was built on wood and have the purpose to assess the performance of the AIC in a typical space of an office room with 6 m wide, 12 m deep and 3.5 m high. Two external openings of 1.2 m x1.2m are located in the smallest façade. The different steps of the experimental procedure are presented in Fig. 5. The surface reflectance of the physical model is presented in Fig 6. The quantitative and qualitative assessment of the AIC was done in this model in two scenarios. One of them is a reference case (without AIC), although the other was the test case (with AIC). The AIC was installed under the roof on the shorter wall-oriented north.

Fig. 5 - Experimental procedure

(a) **(b)**

Fig. 6 - (a) Interior photometric properties; (b) Exterior anidolic element reflectance

4.2 Daylight Level Measurements

The lighting performance is generally measured by the illuminance level (lux) and Daylight Factor (%) (Sharples & Lash, 2007). To validate subjects' responses and the numerical results, physical measurements, in terms of illuminance level, were made with the physical scale models (reference and test model) during the period of the collection of the subjective data under the same outside conditions. The illuminance level was taken at the level of the working plan height (0.9m) and performed for three points: A (at 3m from the window), B (at the middle of the space), and C (at 9 m from the window) in the central axis by using hand light meter in daylight condition (Fig. 7 and Fig. 8). The measurement of the exterior and interior values of illuminance was conducted in the city of Biskra on 06 January 2017 under overcast sky conditions. Besides the illuminance level, the daylight factor (DF) was also considered in this research to study the AIC effectiveness to illuminate the deep areas. This metric is the ratio between outdoor illuminance to indoor illuminance in the overcast sky.

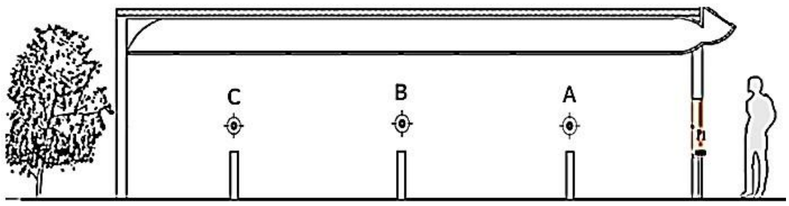

Fig. 7 - Sensors location in the physical test model

Fig. 8 - Luxmeter used in the experience

Daylighting can be studied by using the ‘Climate Based Daylight Modelling’ approach. This approach involves the calculation of the indoor illuminance at predefined time-steps, usually for a full year period by using several metrics such as Daylight Autonomy, Continuous Daylight Autonomy, Maximum Daylight Autonomy, Useful Daylight Illuminance, and Annual Light Exposure (Shen & Tzempelikos, 2012). The energy-saving can be predicted using Daylight Autonomy (DA) (%) which represents the percentage of time over a user-set period where the illuminance level at a particular point exceeds a certain minimum. In this study, the simulations were performed in order to supplement the experimental study and to coved parameter variations that were not possible in real conditions. The simulations run was effectuated using the Daysim 3.1b program. This software has been used in several studies (Jung & Kwon, 2018). The physical conditions of the numerical model for daylight are modeled in Ecotect and simulated with Daysim. The model has the same geometric and photometric characteristics of the experimental physical scale model (Table 2). The sky model was generated by introducing local weather data of Biskra in Daysim.

Table 2 - Geometric and photometric characteristics of the numerical model

Model Characteristics	Dimentions (m)	
Model geometry	Wide	6
	Hight	3.5
	Depth	12
Window geometry	Wide	1.2
	Hight	1.2
	Elevation above ground	0.9
Interior photometric properties (Reflectances%)	Walls	50%
	Floor	40%
	Ceiling	92%
	AIC	96%

In addition, daylight metrics such as Daylight Factor (DF) and Daylight Autonomy (DA) were calculated in the numerical model (Fig.9) at the level of the working plan (0.9m) using a grid resolution of 0.5mx0.5m (twenty-one points were defined along the central axis). For calculating DA, the target illuminance value of 300lx was used as an input [63, 60]. The calculations have been performed in two scenarios. The first one taken as a reference case (without AIC) while in the second simulation we added an AIC. Daylight simulation was run for each actual working hour from 8 am to 5 pm over a whole year with a time-step of 5 minutes. The space (scale model box) is considered without the dynamic shading device installed. The calculation depends on the minimum illuminance threshold, the specified user occupancy, and the type of blind control used. The simulation parameters in Daysim are given in Table 3.

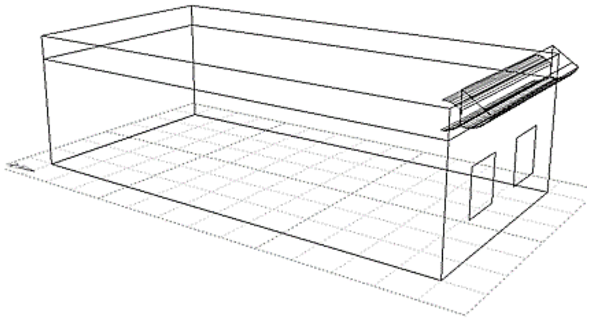

Fig. 9 - Numerical model

Table 3 - Simulation parameters in Daysim

Simulation parameters	Value
Ambient bounces (ab)	6
Ambient divisions (ad)	1000
Ambient super samples (as)	0
Ambient resolution (ar)	300
Ambient accuracy (aa)	0.1

4.4 Subjective Data

During the measurement period, a questionnaire was carried out to collect subjective information about the indoor daylight quality and the need to use artificial lighting. The subjective assessments were conducted with 62 221 master students in architecture, aged 20~23 years old where the participants perceive daylighting in the models in the three-view spots (Fig. 10). For this reason, the survey was conducted in two sessions. In the first one, thirty-one subjects (1-31) were exposed to the reference model where the questions were repeated for each view sport. In the second session, other thirty-one subjects (32-62) were asked to answer the same questions in the test model. In this investigation, four questions of twenty were selected according to the study objectives. The participants were asked to observe daylighting in the physical models and give their opinion about satisfaction with daylighting (Question 1 and Question 2). Question 3 and Question 4 are related to artificial lighting. The questions used in this investigation were based on many studies.

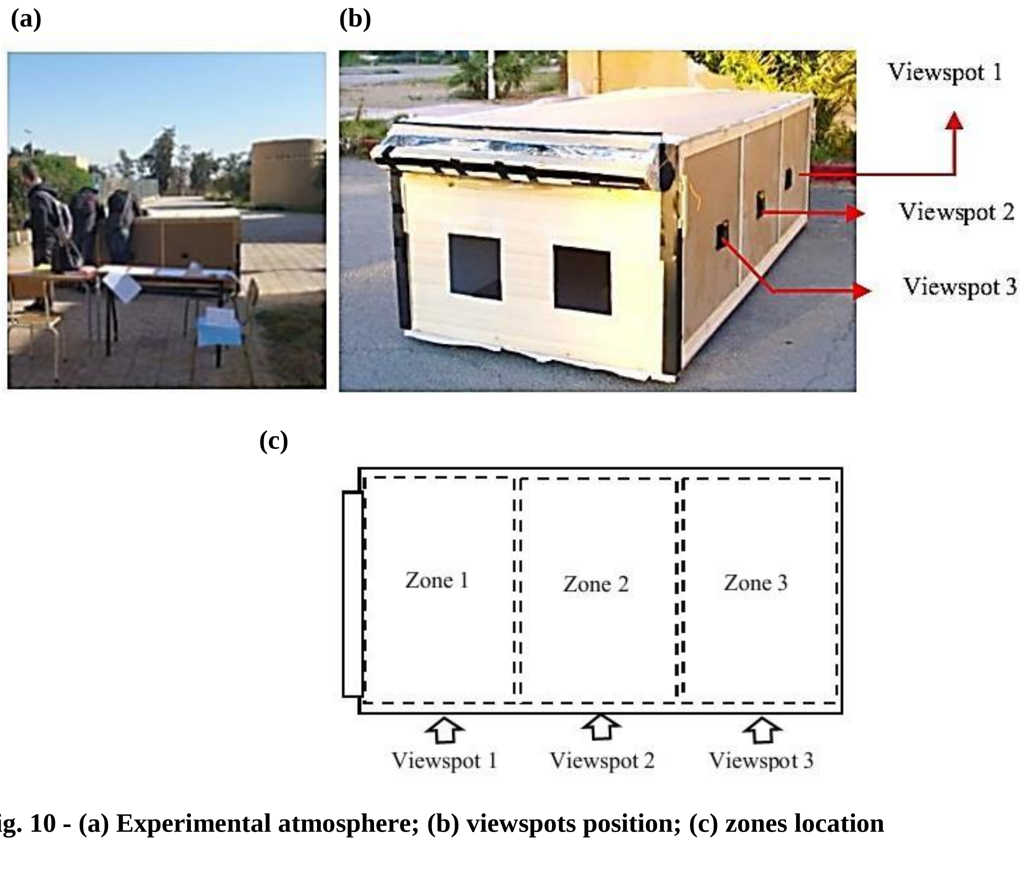

Fig. 10 - (a) Experimental atmosphere; (b) viewspots position; (c) zones location

5. Results

5.1 Objective Results

The result from the measurements (Table 4) shows that in the reference case without AIC: the percentage of the passive area, where the illuminance level above 300 Lux, is 19 %. The data recorded indicates that the daylight received in the reference room was not uniformly distributed and insufficient to provide a good illuminance level. The illuminance values recorded were situated between 59 lux and 3256 lux and the Daylight Factor values are below 1% in more than 80% of the area. In addition, the area located near the window (1-2m) has a very high light intensity which create discomfort visual condition (glare) and as a consequence, all of office area need to use artificial lighting. On the other hand, in the model equipped with AIC, testing points A, B, and C have illuminance levels meeting the standard requirement of 300 lux in nearly 98% of space with DF values situated between 3.47 and 2.15. The percentage of the passive area is very important covers nearly all the space. In this case, the glare risk is significantly decreased and less than 2 % of the office space area needs to use artificial lighting. Besides, results given in Fig. 11 shown that the simulation results suggest a good correlation with the measurement results. In the test case, the DF values calculated are situated between 4 % (near the windows) -1.9 % (in the depth) and were below the standard level especially in the middle and at the bottom of the reference space (< 1%).

Table 4 - Measurement results

Measurement points in the central axis (P)	**Distance from the Windows (m)**	**Interior illuminance measured (lux)**		**Exterior illuminance measured (lux)**	**DF measured (%)**	
		Reference case	**Test case**		**Reference case**	**Test case**
P1	2.4	634	1139		1.93	3.47
P2	5.6	125	835	32750	0.38	2.54
P3	8.8	73	707		0.22	2.15

(a) **(b)**

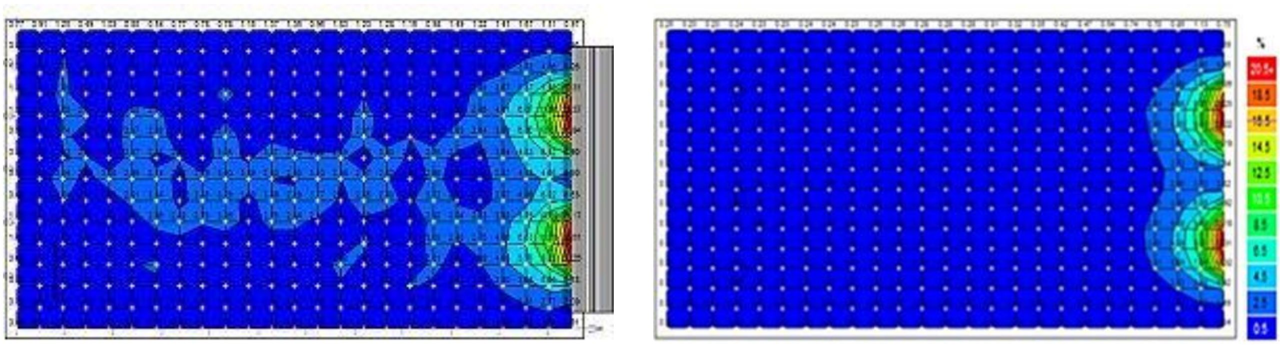

Fig. 11 - (a) DF in the test model; (b) DF in the reference model

In addition, the investigation demonstrates that the proposed transporting daylighting system (AIC) can significantly reduce the use of artificial lighting and energy lighting consumption. The simulation results given in Fig. 12 show a noticeable difference in the DA300 lux values in the two scenarios. In the reference model, only 17.14% of energy can be saved: 67% of DA300lux was obtained in the zone 1 (near the windows) and 0% of energy saving has been recorded in zone 2 and zone 3 (more than 70% of the space have DA300lux less than 5%. In the equipped with an anidolic ceiling, more than 83.80% of energy for electrical lighting can be saved. The daylight autonomy is higher than 90% in 95% of the area.

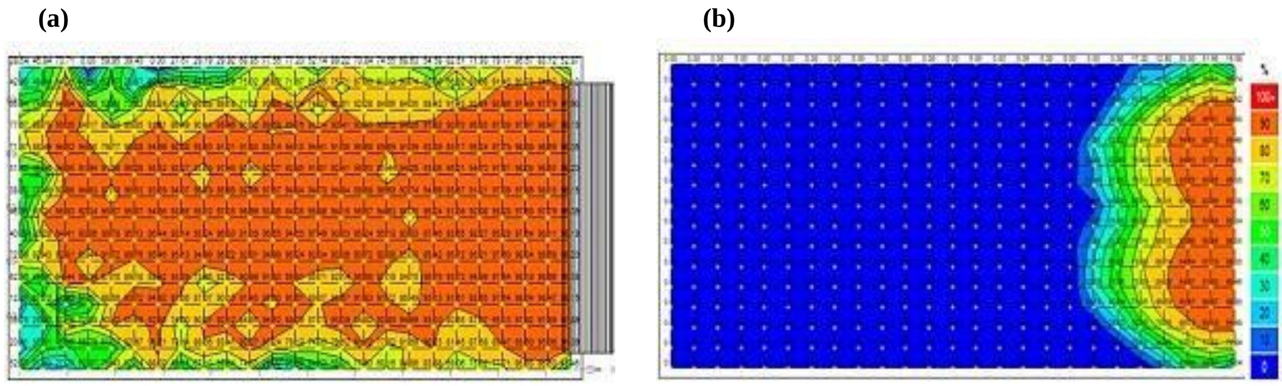

Fig. 12 - (a) Daylight Autonomy300lx; (b) reference model

5.2 Subjective Results

The graphs are given in Fig. 13 present the level of the pleasantness of the participants toward the interior daylight quality in both scenarios and the different visual field (view spot 1, 2 and 3). The results can indicate that more than 67% of participants felt pleased with the luminous environment of the test model and less than 16% were satisfied with daylighting in the reference model. In the first view spot, the level of pleasantness reported by the subjects were approximately the same in the two models, which decrease with the room depth.

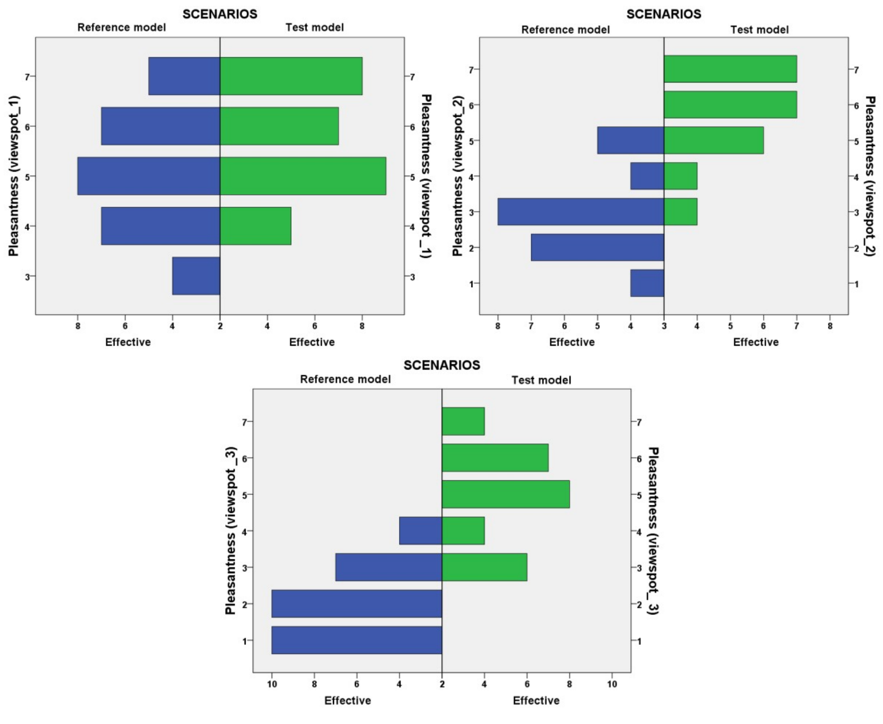

Fig. 13 - Pleasantness analysis in the three viewspots

The responses of the level of light given in Fig. 14. showed that the participants were more satisfied with the level of light in the test model compared with the reference case. The results show that 90.32% of the subjects were satisfied in the near part, 77.41% in the middle and 74.19% in the rear part of the room and consequently, the subjects were dissatisfied with the quantity of light in the reference model, 9.67% of participants give negative response in the first view spot, 74.19% in second and 83.87% in the depth.

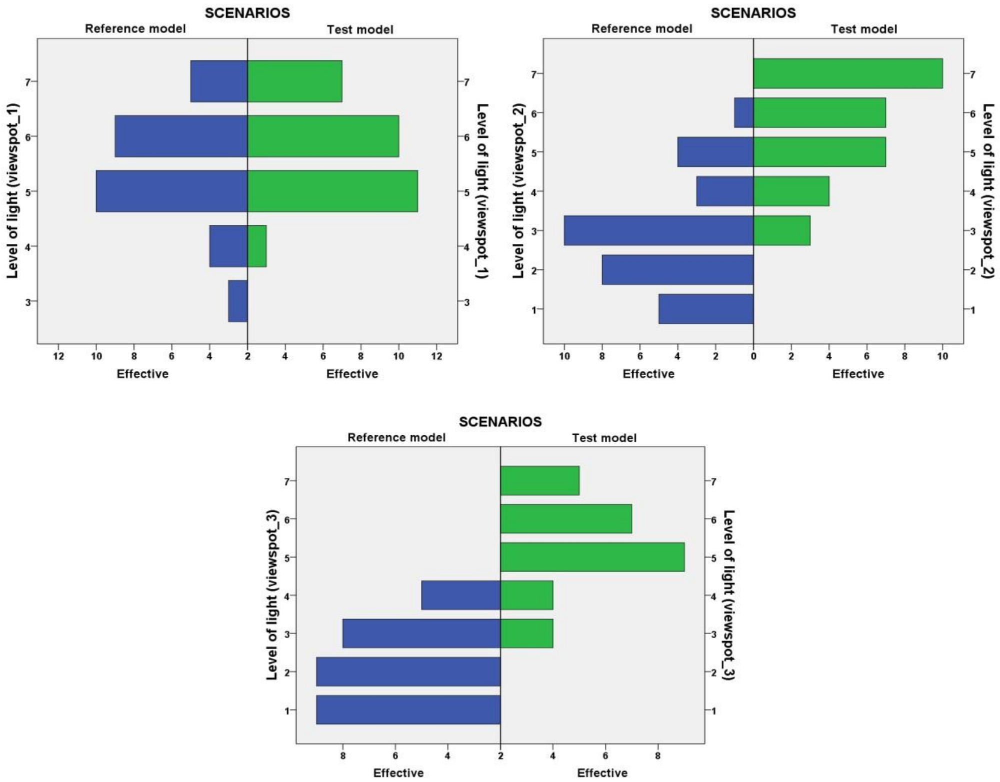

Fig. 14 - Level of light in the three viewspots

However, satisfaction with the level of light in both scenarios determines the level of luminous comfort. Some 73.4 % of the participants reported that their level of pleasantness was the same as their level of satisfaction with the quantity of natural light. The third question was posed to see if the subjects need to use artificial lighting in the space. As can be seen in Fig. 15, the need to use artificial lighting is important in the reference model, which increases with room depth. Some 27 subjects of a total of 31 (in the middle) and 31 of 31 (in-depth) consider that daylight is restricted, artificial lighting needs to be used in the reference room and only 08 subjects need to use artificial lighting in the test model. Therefore, the comparison of the collected data illustrated in Fig. 16 showed that in the reference model, 62 335 subjects (78.48%) give negative responses. Some 45.17% of the participants need to use artificial lighting in the second zone and 54.38% in the third zone. In the test model, only 17 participants (21.52 %) perceive that the light is not sufficient and space needs to be illuminated with artificial lighting, 58.82% were given negative responses in the middle of the space and 41.18% in the rear part of the model.

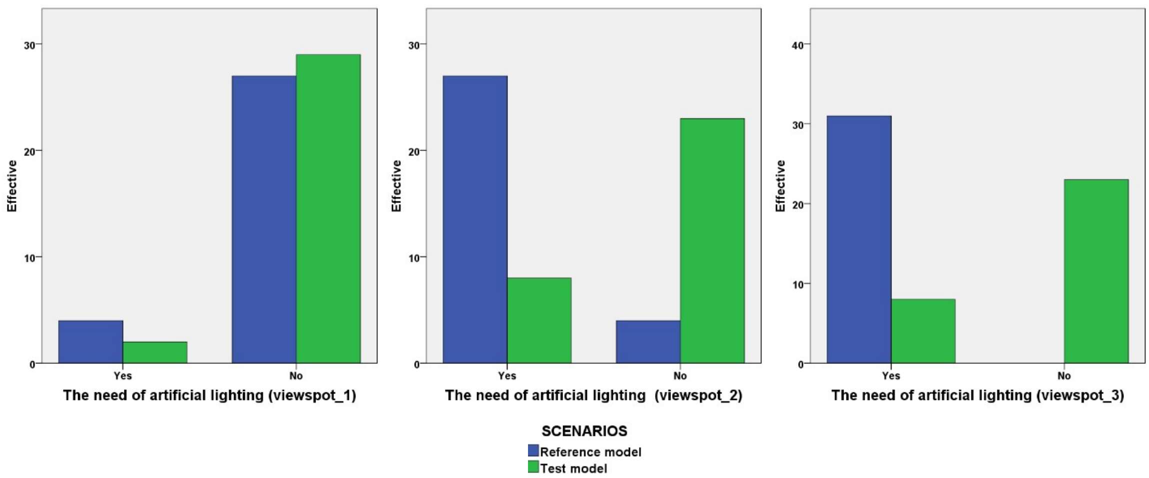

Fig. 15 - The need to use artificial lighting in the three viewspots

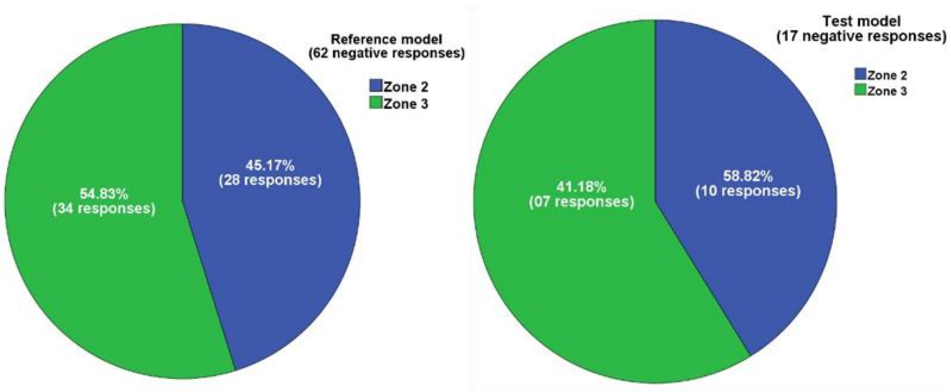

Fig. 16 - The need to use artificial lighting in the different zones in both models

From the quantitative and qualitative results given in the above section, it is clear that adding an Anidolic Integrated Ceiling could effectively increase the interior illuminance daylight level and improve the visual comfort of users in deep office spaces. The proposed system works as a daylight regulator; it reflects much more daylight to the areas located far from the windows and contributes to giving higher Daylight Autonomy values. In addition, the participants prefer daylight where it is available and lower satisfaction with luminous environment conditions reflected the upper need to use artificial lighting reflected.

6. Conclusion

The paper shows a detailed process to develop and design a specific anidolic daylighting system for deep office spaces to enhance visual comfort and energy performance under high exterior illuminance level of the city of Biskra (Algeria) using simulation and experiment methods. According to the results, it is obvious that the influence of using AIC of natural light distribution is very significant. The findings show that the use of the Anidolic Integrated Ceiling led to more natural lighting in the building, expanding the area of daylighting that meets occupant's visual comfort and increase the energy saving without specific problems of glare, Better values of DF were obtained in especially in the depth (1.9%). Numerical simulation using Daysim software confirmed the AIC performance to improve the daylight autonomy of the space and more than 80% of the energy consumption for electrical lighting of the building can be saved; however, the level of illuminance cannot reach the comfort levels to perform visual tasks worsening electric consumption for artificial lighting in the reference case (DF<0.2% in the bottom of the space with an energy saving of about 17 %). Subjective evaluation of lighting through a scale model is an important complement to physical and numerical measurements. Overall, the responses obtained from 31 of a total of 31 subjects showed that in the model equipped with AIC, 67% of participants were satisfied with their daylighting, 74.19% considered that the level of light is sufficient and only 21% need to use artificial lighting. This investigation can be useful and gives, to architects and engineering, an overview of the AIC design and performances under similar climate conditions.

One of the limitations of this research is that the technology of Anidolic Integrated Ceiling has not yet been adopted in the city of Biskra, making an exhaustive investigation impossible. In addition, the available materials used for the realization of the anidolic system have a reflectance (96%) lower than that recommended to ensure maximum performance of the system (up to 96%). In future research, we suggest realize a real model of the AIC with a scale of 1:1 and evaluate its effect on the occupants' satisfaction in real conditions. In addition, a quantification of the energy savings of this system for lighting, heating, and cooling can be another research axis.

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