718: Investivating the performance of anidolic vertical openings under real conditions in Greece

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Abstract

The objective of the current study is to investigate the performance of anidolic vertical openings under real climatic conditions in Greece. For that purpose, an anidolic ceiling was installed in a scale model and was placed next to a reference model equipped with a conventional facade. The models had identical interior photometric properties and geometry. Both models were placed in an unobstructed site and the indoor daylight levels were recorded on specific points of the working plane. Furthermore, the effect of orientation on the formation of indoor daylight conditions was studied by rotating the models, in order to face different directions. The findings of this experimental analysis, which are thoroughly presented in the current paper, indicate that the particular daylight system offer a great potential for enhancing the daylight conditions in deep, side lit spaces, since it seems to perform efficiently under both overcast and clear skies.

Keywords: daylighting, advanced daylight systems, anidolic openings

1. Introduction

The rational consumption of electricity in buildings is currently one of the main objectives of the forthcoming measures for environmental protection in Greece, since the majority of local power plants rely mostly on fossil fuels combustion. It is worth mentioning that artificial lighting accounts for up to one third of electricity consumed in office buildings, although ambient illuminance reaches high levels and is available during most of the usual working hours. In order to harness this energy, several advanced daylight systems have been developed, which exploit direct and/or diffuse illuminance. Among those, anidolic systems installed on the building's facade seem to be ideal for the densely built greek urban areas, since their primary objective is to utilize sky luminance from the upper parts of the sky vault.

Daylight is collected with the aim of a parabolic concentrator and is transported through a light duct positioned below the roof. It is finally distributed at the back of the room through a parabolic reflector positioned at the duct's exit [1].

The performance of anidolic daylight systems has been thoroughly studied, but mostly under overcast sky conditions [2], [3]. The objective of the current paper is to investigate whether they can perform efficiently in mediterranean climates, where clear skies dominate.

2. Description of the experimental procedure

The performance of anidolic vertical openings was studied under real conditions by monitoring the daylight levels prevailing on two physical models. The use of scale models is an invaluable tool in the design process of a daylighting system, since they allow the assessment of its performance; due to the physical properties of natural light, the photometric measurements taken inside a physical scale model approximate those existing in a full-scale building [4]. Besides, a direct visual examination of the interior is allowed, providing information about glare and contrast in the space.

The models were made of hard paper and were built at a scale of 1:15 with a typical office configuration. They had identical geometrical characteristics and interior photometric properties (Table 1). In fact, the reflectance of the materials used for the construction of the models, as well as the visible transmittance of the glazing were measured according to the method proposed by CIE [5]. The models were placed side by side on an unobstructed site facing the same direction (Fig. 1). One was regarded as the reference case, while the other was the test case, where the anidolic system was installed above the window on a suspended ceiling. The geometrical configuration of the anidolic system is presented schematically on Fig. 2.

The measurements were conducted in July 2007 under clear sky conditions during the usual working hours (09:00-17:30) with a time step of

Table 1: The geometrical characteristics and the interior photometric properties of the test modules.

Room geometry			**Window geometry**		
Width	Length	Height	Width	Height	Sill height
4.50m	7.00m	3.00m	3.85m	1.75m	1.00m
Interior photometric properties					
Walls:	80%	Floor:	60%	Ceiling:	80%

two minutes and included the recording of illuminance prevailing on the horizontal plane of the ambient environment, as well as in the interior of both models and specifically across the middle of the models on an axis perpendicular to the window wall at a plane representing the working surface (0.80m). Two sensors were installed at the test case model at point A close to the window (0.50m from the window wall) and point B below the exit of the light duct (4.40m from the window wall). Illumination was recorded In the interior of the reference case model at point C, which is at the same position with point A (4.40m from the window wall of the reference model).

The contribution of the anidolic system on the formation of indoor daylight conditions was evaluated by comparing the illumination levels prevailing in the interior of the two models during a typical day. The analysis of the system's overall performance was attempted by studying its effect on the increase of illumination at the rear of the room, as well as on the uniformity of daylight distribution.

Furthermore, the effect of the facade's orientation on the system's performance was also studied by rotating the platform with the two scale models every 15 minutes, in order to face consecutively South, East, North and West.

The obtained illuminances were particularly high, both in the interior of the scale models and the ambient environment. The variation of ambient illuminance during a typical day is presented on Fig. 3. It ranges from approximately 40klx to 100klx and obtains its maximum values during afternoon (13:00-15:00).

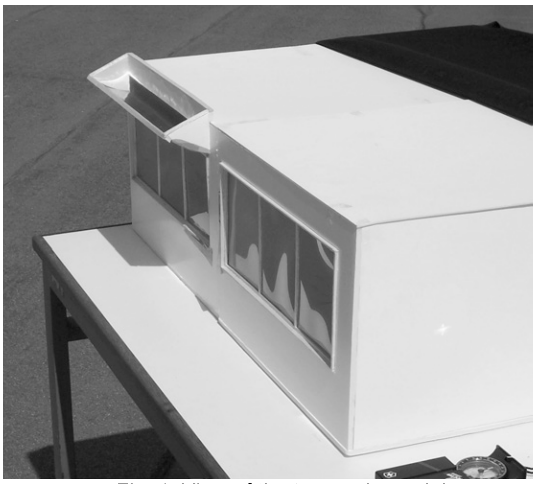

Fig. 1. View of the two scale models.

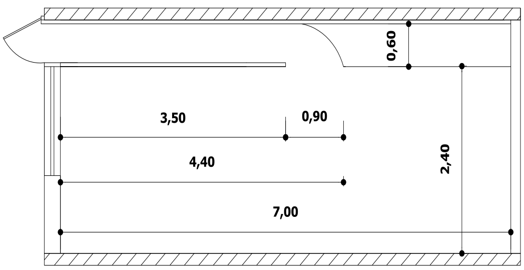

Fig. 2. Cross section of the test case model, showing the geometrical properties of the anidolic system installed on a suspended ceiling.

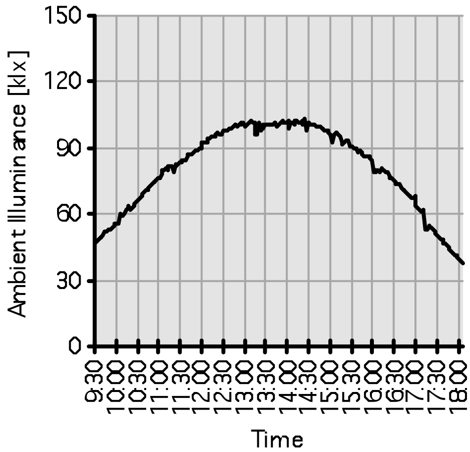

Fig. 3. The variation of illuminance on a horizontal plane on the ambient environment during a typical day of the measurement period.

3 Assessing the performance of the anidolic system

The values of illumination monitored during a typical day at points A and B of the test case model, as well as at point C of the reference case model are graphically plotted against time for the cases that the models are orientated due South (Fig. 4), East (Fig. 5), North (Fig. 6), and West (Fig. 7).

In the case of south orientated models, illumination reaches its maximum levels on the afternoon, while it is minimized during the morning and evening hours (Fig. 4). The line representing the illumination at point B approaches the respective curve for point A of the test case model on the afternoon (13:30-15:30), while at the same time the distance between the lines representing the illuminance of points B and C becomes wider, indicating that during this period direct sunlight of high illuminance enters the anidolic system and is distributed at the rear zone of the model. In fact, the increase of daylight levels at the zone beneath the exit of the anidolic system ranges from 15% to 40% (B:C). Moreover, the difference on illumination between areas near the window and at the rear of the test model is decreased from 35% to 6% (B:A) during the day; this decrease is not only attributed to the increase of daylight penetration at the back of the room due to the anidolic system, but also on the reduction of daylight levels in the front of the room, since the projection of the aperture's entry acts as a shading device (overhang). Therefore, it is concluded that during the whole day, but mostly during the afternoon hours, the anidolic system not only enhances the daylight levels deep into the space, but also improves the uniformity of daylight distribution.

In the case of east orientated models, the three curves representing the illumination monitored at points A, B and C have the same trend (Fig. 5); maximum values are obtained in the morning (09:45-11:45), while as time goes by daylight levels decrease and acquire similar values. The

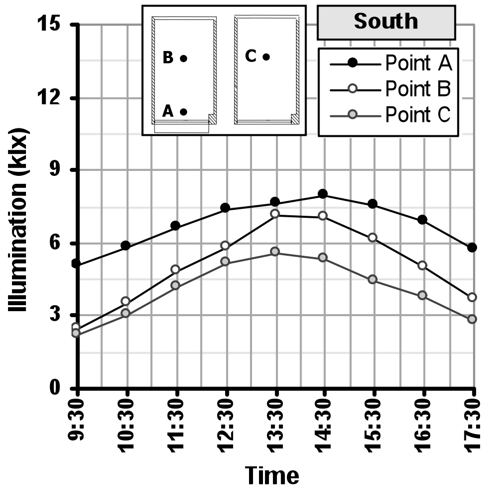

Fig. 4. Ilumination monitored at points A, B and C of the scale models during the day, when the models are orientated due South.

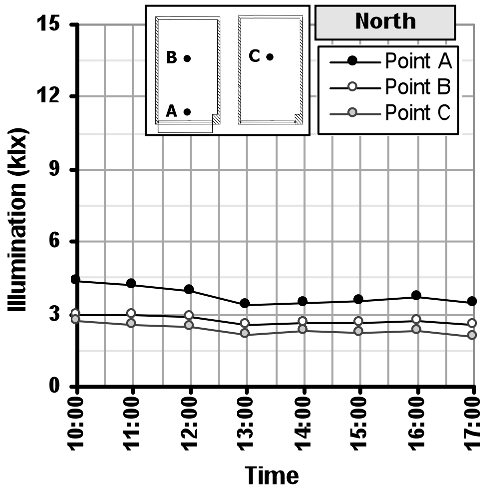

Fig. 6. Ilumination monitored at points A, B and C of the scale models during the day, when the models are orientated due North.

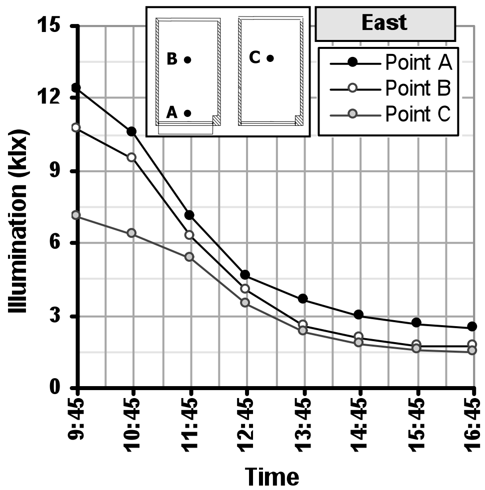

Fig. 5. Ilumination monitored at points A, B and C of the scale models during the day, when the models are orientated due East.

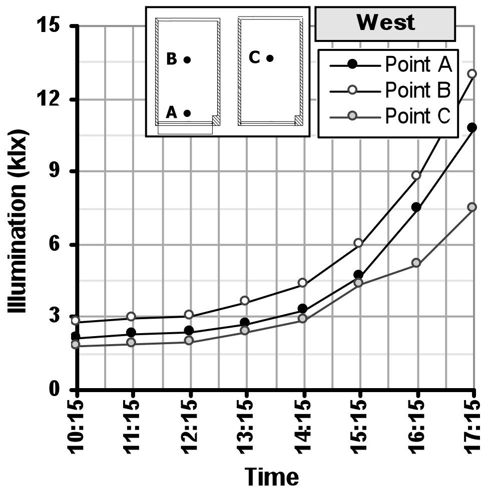

Fig. 7. Ilumination monitored at points A, B and C of the scale models during the day, when the models are orientated due West.

quantitative contribution of the anidolic system, expressed as the increase rate of illumination at points B and C, reaches 50% during early morning and gradually falls to 12% at the end of the day. Furthermore, daylight seems to be distributed more evenly during morning, mainly due to the increase of illumination at the rear of the room. More specifically, the daily difference between the observed illumination on points B and A is on average equal to 22%; this percentage is reduced to 10% in the morning.

Similar conclusions can be reached in the case of west orientated models, with the exception that the peak values are observed in the evening (Fig. 7). In that case daylight levels are increased at the rear of the room during the whole day at an average rate of 20% in absolute values, but particularly in the evening (15:00-17:00) the increase reaches 40%. However, the distribution of daylight is not affected enormously, since the daily average difference on daylight levels at points B and A equals 24%, while it reaches 18% during the evening.

In the case of north orientated models, illumination has a relatively constant value throughout the day. The curves representing the illumination on points A, B and C of models are parallel and close to each other (Fig. 6). Still, the presence of the anidolic system helps towards the enhancement of daylight levels, since there is an average increase of 16% on the illumination observed at point B compared to the relative values at point C. This difference is constant through the day. The anidolic system seems to contribute to the even distribution of daylight, but only at a limited extent, since the daylight levels deep into the space are not dramatically affected. However, the average difference between illumination at point B and A equals 26%, which is not much higher than the respective percentages obtained in the previous cases.

3. Conclusions

From the above analysis, it is obvious that the anidolic system performs well for each orientation. The daylight levels observed at point B are higher than those at point C during all day long. In absolute values, this increase ranges from 22% (east orientated models) to 27% (south orientated models) on an average daily basis; it is therefore more substantial in the case of a south orientated system.

Furthermore, it is worth mentioning that the system's performance differentiates during the day. In particular, during the periods that it receives direct illumination the daylight levels below the exit of the duct are dramatically increased. Table 2 indicates the performance of the system during the periods that it receives direct illumination, expressed as the percentage of difference on illumination levels prevailing on points B and C. Although a south orientated model seems to perform better on an average daily basis, the increase of illumination is higher in the case of east and west orientated systems, indicating that the penetration and the transmission of solar rays through the light duct are more efficient at low solar altitudes.

On the contrary, when the anidolic system is working with diffuse daylight, it performs better when it is orientated due South (Table 3). In that case, the uniformity of daylight distribution is better achieved.

The assessment of the system's performance with respect to its orientation, as well as the estimation of the period that it reaches its maximum performance can play an important role on the daylighting planning at the early stages of the building design. The building type and the schedules of its use are crucial parameters, upon which the decision for integrating advanced daylight systems, such as the anidolic ceiling, can be reached. For example, for a space that is orientated due West and is used mostly in the morning (ie classroom), the integration of an anidolic ceiling may be not the best solution for the enhancement of its visual interior environment.

Table 2. The performance of the anidolic system during the periods that it receives direct illumination, expressed as the percentage of difference on illumination levels observed at points B and C.

Orientation	**Time**	**Performance B:C (%)**
South	12:30-15:30	34%
East	09:45-11:45	39%
West	15:15-17:15	36%
North	10:00-17:00	16%

Table 3. The performance of the anidolic system during the periods that it receives diffuse daylight, expressed as the percentage of difference on illumination levels observed at points B and C.

Orientation	**Time**	**Performance B:C (%)**
South	09:30-12:30 15:30-17:30	21%
East	11:45-16:45	14%
West	10:15-15:15	17%
North	10:00-17:00	16%

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