Investigating the performance of Anidolic Daylighting System with respect to building orientation in tropical area

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***Abstract*— Producing available daylight in building is a crucial issue for reasons of energy-efficiency as well as improvement of occupant's health and well-being. Moreover the orientation of building is an important factor for the construction particularly with respect to daylight. The objective of this research is to investigate 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 equipped with a conventional facade. The models had built same in interior photometric geometry and properties. Both of them were placed in an unobstructed site and the levels of indoor daylight were measured on specific points of the models. In additional, the effect of orientation on the formation of interior daylight conditions by rotating the models, because of face different directions was studied. The results of this experimental analysis, that are thoroughly presented in this article, point to that the particular daylight system offers a great potential for increasing the daylight**

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conditions in deep-plan building, since it seems to perform efficiently in tropical area specially on south orientation.

Keywords- Anidolic Daylighting System; Building orientation; Tropical area; Scale model

I. INTRODUCTION

Daylight produces outside illuminances that often exceed the required illuminances for office rooms. Making available daylight in office buildings can result in significant electricity savings. In addition, daylight improves the occupants' performance and well-being [1]. In recent decades, a variety of daylighting technologies have been developed for this purpose [2].

Over the last decades, concern in daylighting, between other solar applications, began to be improved in an effort to decrease energy consumption. Today, with the advancing problem of global warming, daylighting is regarded a very significant strategy to change the electric energy demanded by artificial lighting however efficiently decreasing peak electrical loads Daylight is collected with the aim of a parabolic concentrator. This device carries daylight through a light duct positioned under the roof. It is lastly distributed at the rear of the room through a parabolic reflector positioned in the duct's exit [3].

The performance of Anidolic Daylight Systems has been methodically studied, but mostly it is done with simulation [4]. The objective of the current paper is to investigate performance efficiency with model and effective orientation in tropical area.

II. Structure of advanced Anidolic Daylighting System

One of perfect non-imaging optics its application for capturing daylight is ADS. It was used to set up novel daylighting systems that develop on the efficient collection and redistribution of the diffuse component of daylight purpose. Anidolic system means an: without and eidolon: image that it has three key components: the collector on the outside of the facade, the rectangular mirror light duct and the distributing part (distributor) at the end of the duct [5]. The system was designed as a result of the non-imaging optics theory.

The most important part of this unit is collector. Stephen Wittkopf [6] in 2010 researched this topic and in this study was advanced type 5 "Fig. 1" which is to capture daylight a better performance in tropical area.

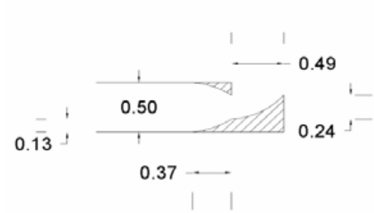

Figure 1. Type 5 of Anidolic's collector

The other important design criteria for ADS have been introduced and their influence on such systems' performance has been analyzed [7]. Therefore, in advanced ADS is employed these parameters (Table I).

TABLE I. PARAMETERS OF ADVANCED ADS

Parameters of ADS		
ADS geometry	Width Length Height	3 m 9 m 0.5 m
Interior photometric properties	Reflectivity	84%

III. Description of the experimental procedure

The performance of the ADS was researched in real climatic conditions by examining the daylight ranges on two physical models. The use of scale models is an usual tool used in the process of design in a daylighting system, while they let the evaluation of its performance; because of the physical properties of natural light, the photometric measurements taken inside a physical scale model fairly correct those existing in a full-scale building [8]. In addition, a direct visual examination of the interior is permitted, providing information about contrast and glare and in the space.

A. Model configuration

The models were built of plywood and were made at a scale of 1:10 with a typical office configuration. Two model rooms were structured in 2.5 m height × 5.0 m width × 9.0 m length [9]. They had equal geometrical properties and interior photometric characters that are shown in Table II [10]. Actually, the material reflectance used for the building of the models was measured according to the method proposed by CIE [11]. The models were put next to on an unobstructed site with the same orientations and were placed inside of UTM site. One of them is a reference case, although the other was the test case, and the Anidolic System was installed under the roof. The geometrical configuration of the ADS is shown "Fig. 2".

TABLE II. CONSTANT PARAMETERS IN MODELS

Constant		
Room geometry	Width Length Height	5 m 9 m 3.5 m
Window geometry	Width Height WWR	4m 1.70 m 30% - (2.5m*1.7m)
Interior photometric properties	Wall Floor Ceiling	50% 20% 80%

Figure 2. Construction and Installation of scale physical model on selected site

B. Experimental procedure

The measurements were performed on January 4 under Johor sky conditions for the period of the usual working hours from 09:00 until 19:00 with a time step of two minutes. It be included the recording of illuminance on the horizontal plane of the ambient space, in addition to in the indoor of the two models and in particular across the center of the model tests on an axis perpendicular to the wall of in a plane representing the working surface with a height of 0.80m [12].

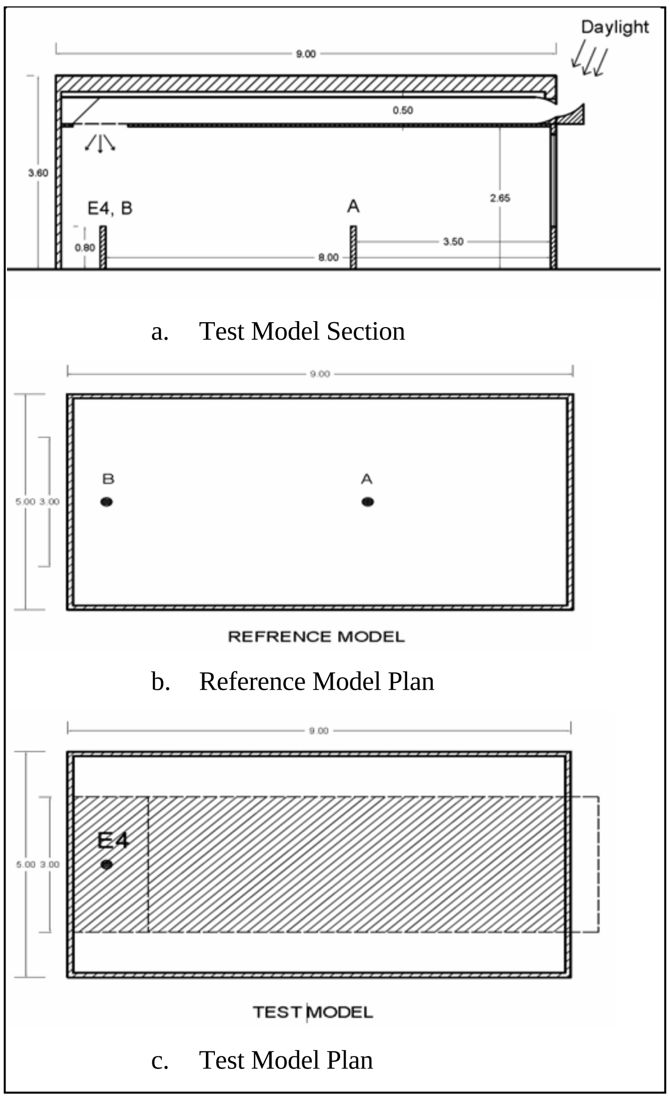

Figure 3. Geometrical configuration of models and the ADS device

One sensor was installed in the test case model at point E4 under the rear of the light duct (8m from the window wall) and two sensors in the reference model. Illuminations were recorded in the interior of the reference case model at point A (3.5 m from the window wall) and point B that is at the same position with point E4 that it is placed 8m from the window wall of the reference model. Window produces optimum daylight in the building until 3.5 m from window wall [13].

The contribution of the ADS on the configuration of inside daylight conditions was assessed by comparing the alike illumination levels 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 the illumination at the deep of the room, as well as on the daylight uniformity distribution. In additional, the result of the orientation of facade on the system's performance was also tested by rotating the stage with the two scale models as to manage face successively South, East, North and West.

The illuminances were achieved both in the indoor of the scale models and the ambient environment. The variation of ambient illuminance during a typical day is shown "Fig. 4". Data in different times were obtained an average of four directions. It ranges from approximately 3klx to 80klx and obtains its maximum values during 11:00 until 14:00.

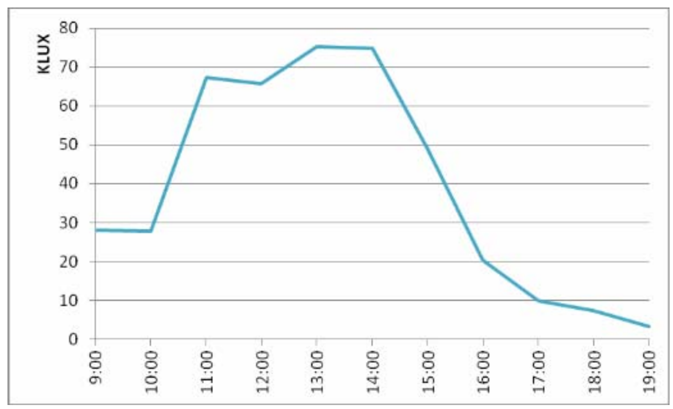

Figure 4. The average of illuminance variation a horizontal plane on the ambient environment during a typical day of the measurement period

C. Absolute Work Plan Illuminance (WPI)

They were measured at different times and directions. According to MS 1525: 2007 [14], the recommended minimum absolute WPI for general office is 300 Lux.

D. Daylight Factor (DF)

DF is defined as the ratio of interior illuminance on a horizontal surface (E_i) to the exterior illuminance on a horizontal surface (E_e) [15].

$$DF = (E_i/E_e) \times 100$$

IV. EVALUATING THE PERFORMANCE OF THE ADS

The values of illumination in a usual day at points A and B in the reference model case, and at the point E4 in test model case in same time are shown. The models are orientated due South "Fig. 3", East "Fig. 4", North "Fig. 5", and West "Fig.

6”. It is necessary to note that values times for four directions are different therefore point values are recorded with ambient space in an instant. Hence the daylight factor is the other option to compare the directions in this study. In additional, The Malaysian guidelines for energy efficiency in buildings [14] recommend that the interior lighting for offices should be between 300 and 500 Lux. For this study, we used the minimum allowable interior illuminance of 300 Lux. These data are employed to investigate the performance of ADS in building orientation.

At the type of south orientated models, illumination arrived at its maximum levels on the during between 11:00 until 15:00 although it is minimized in the morning and evening hours “Fig. 5”. The line representing the illumination at the point E4 increase in the afternoon and reaches a peak (3963 Lux) at 13:00 o'clock. Indicating that during this period daylight of high illuminance enters in the ADS and is distributed in the rear area of the plan in models. Actually the increase of daylight levels in the zone under the exit of the ADS arrive 6 to 11 times (E4:B). The ADS increase daylight penetration at the back of the room moreover it reduces daylight levels in the front of the room, since the projection of the aperture’s entry acts like a shading device (overhang). It is concluded that during the whole day, but mostly during the afternoon hours, the Anidolic system increases the daylight levels deep into the space, in additional improves the uniformity of daylight distribution. Moreover adequate daylight (over 300 Lux) for south orientation is in the morning until 17:00 o'clock which this is office time.

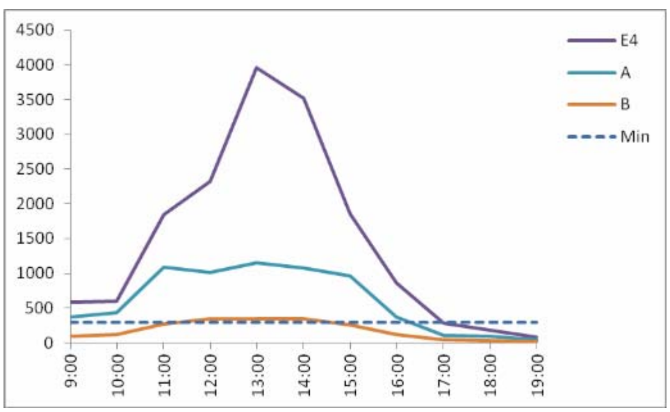

Figure 5. Ilumination monitored at points A, B and E4 of the scale models during the day, when the models are orientated due South.

In “Fig. 6” is shown that case of east orientated models, the three curves representing the illumination monitored at points A, B and E4 have the same trend. Maximum values are achieved in the morning (10:30-12:30), while as time goes by daylight levels decrease and acquire similar values. The quantitative contribution of the Anidolic system, expressed as the increase rate of illumination at points E4, reaches 7 times in the morning (11:00 AM) and gradually decrease at the end of the day. Moreover, the daylight seems to be distributed more evenly during the morning, mainly due to the increase of illumination at the rear of the room. Moreover adequate daylight (over 300 Lux) for south orientation is in the morning until 17:00 o'clock which this is office time.

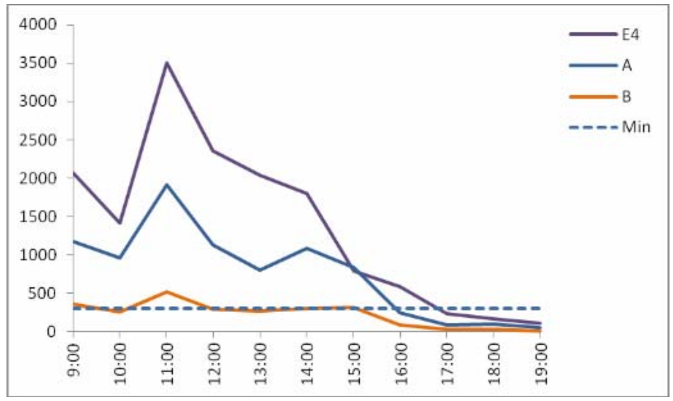

Figure 6. Ilumination monitored at points A, B and E4 of the scale models during the day, when the models are orientated due East.

In the case of west orientated models the peak values are observed in the afternoon “Fig. 7”. In that case daylight levels are increased in the rear of the room during the whole day, while particularly in the afternoon (12-15:30) the increase is high and reaches the peak at 14:00 PM around 3 times (E4:B).

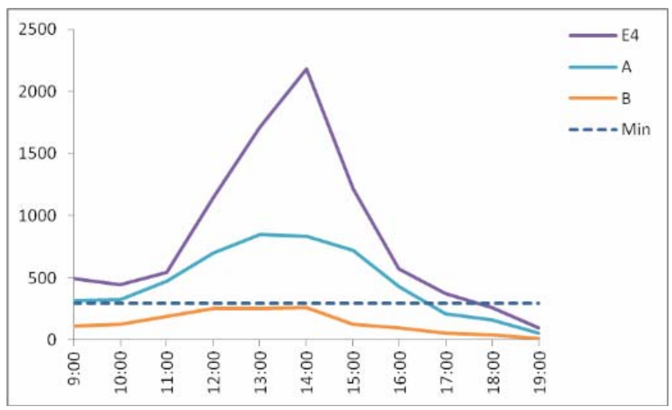

Figure 7. Ilumination monitored at points A, B and E4 of the scale models during the day, when the models are orientated due West.

In the case of north orientated models, illumination has a comparatively constant value throughout the day. In “Fig. 8” is demonstrated the curves representing the illumination on points A, B and E4 of the models are relatively similar. Still, the attendance of the Anidolic system cause to the enhancement of daylight levels, Actually the increase of daylight levels in the point E4 under the exit of the ADS arrive 4 times compared to point B at 13:00. Moreover, appropriate daylight values for office are between morning until 15:30 PM.

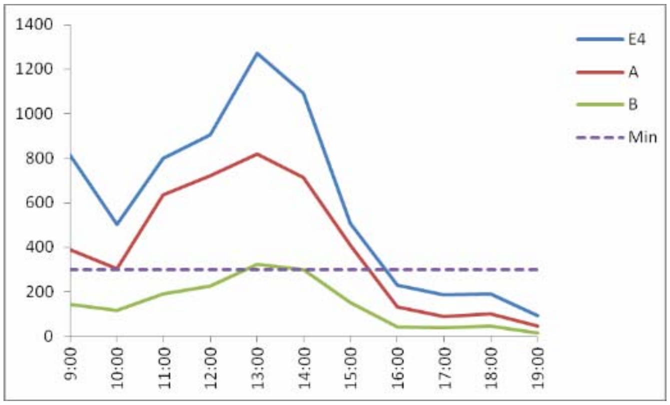

Figure 8. Ilumination monitored at points A, B and E4 of the scale models during the day, when the models are orientated due North.

In "figure 9" is shown illuminance daylight values in under the exit of ADS in during the day in the four directions. According to the graph ADS Enhances the daylight levels in south orientation more than other directions. However uniformity of daylight in the morning and afternoon is approximately equal in this orientation.

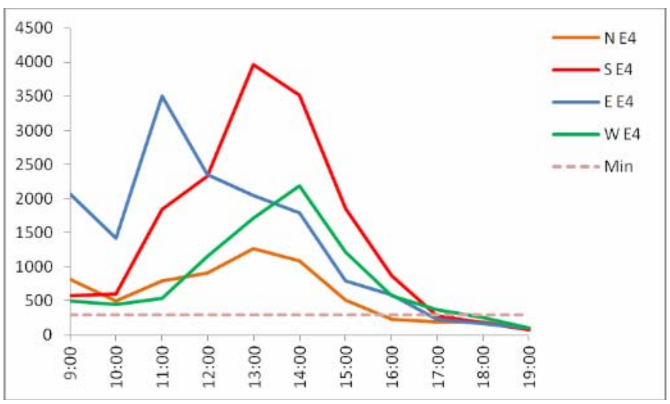

Figure 9. Ilumination monitored at points E4 of the test model in four orientations during the day

Daylight Factor values determine the ratio of interior illuminance on a horizontal surface to the exterior illuminance on a horizontal surface. "Figure 9" illustrates DF values of point E4 in four orientations. Optimum performance of DF is between 2 to 5 in the office room [14] that in this figure have been shown. It is clear that east orientation line exceeds the maximum line in the morning and west direction line is under the minimum line in the morning. Moreover, line in north orientation is down on the minimum line in during the day(10-16:30). However, DF values in South orientation are between minimum and maximum line.

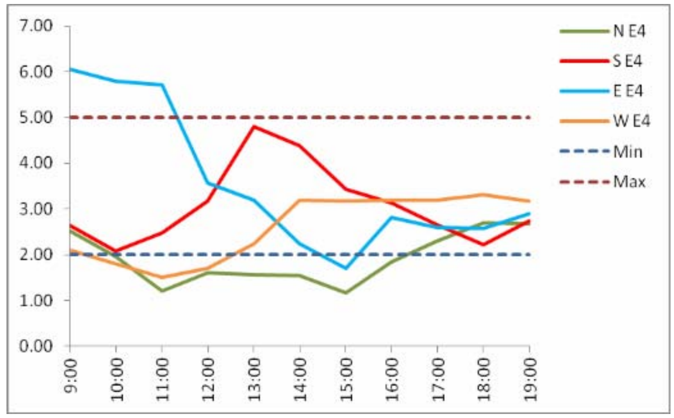

Figure 10. Daylight Factor monitored at points E4 of the test model in four orientations during the day

V. CONCLUSION

In conclusion, the results of this study show the ADS perform well for all orientations. The daylight illuminances at point E4 are higher than those at point B during whole day long. In illuminances values, this increase ranges 4,7 and 3 times are higher than point B respectively in North, East and West orientation at peak hour, however in south direction this value is higher than other orientations approximately 11 times. Table III illustrates the performance of the system in peak hours on point B and E4. Moreover next column is shown during the period that the system receives optimum daylight into indoor room which performance of the south and west orientations are better that other directions. In additional daylight uniformity on during the day is an important issue inside of the office. In East and North orientations illuminances in point E4 between morning and afternoon are not uniform but daylight in South and West in inside of room are uniform and approximate equal in morning and afternoon. In table III DF values in point E4 in four orientations are shown. It is obvious that DF in South oriented model is better than other orientations. These results as a whole indicate that the performance of ADS in South orientation is better than other orientations in tropical area. This study recommends that applications of this device to improve daylight in an office building. Moreover this could research in energy saving potential and cycle cost analysis.

TABLE III. VARIOUS VALUES IN DIFFERENT ORIENTATIONS

Orientation	**Performance B:C**	**Optimum daylight**	**Uniformity in during day**	**DF**	
South	11 times in peak hour (13:00)	9:00-17:00	Uniform	All day	Well
East	7 times in peak hour (11:00)	9:00-16:30	Nonuniform Morning is higher than evening	9:00-11:30	Over than Max
				14:30-15:30	Lower than Min
West	3 times in peak hour (14:00)	9:00-17:30	Uniform	9:30-!2:30	Lower than Min
North	4 times in peak hour (13:00)	9:00-16:00	Nonuniform Morning is higher than evening	10:00-16:30	Lower than Min

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