

Daylighting Strategy for Kuwait Autism Center Eliminates the Need for Electric Lighting

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ABSTRACT: Adequate daylighting contribution in buildings saves energy required for artificial lighting as well as it improves the luminous quality of these daylit spaces. Studies have showed that daylit classrooms are good for improving the academic performance of students. And therefore, adequate daylighting becomes a building design mandate for places like classrooms.

This paper discusses a case study of the architectural design of Kuwait Autism Centre (KAC) that adopted, as a major design definer, the provision of adequately lit educational spaces for autistic people. After the conceptual architectural design was proposed according to the client requirements, a complete daylighting study was conducted to all the educational facilities of the centre. The results were in the form of a set of design recommendations that were implemented in the design development stage. This paper will show the final design development of the KAC facilities after implementing the daylighting design recommendations. It also summarizes these recommendations and explains the daylighting physical model experiment and analysis that led the architects to adapt them. And at the end it shows the results of light levels and amount of savings in energy achieved by the contribution of the daylighting strategy for the centre.

Keywords: daylighting, energy, architectural design, electric lighting, Kuwait Autism Centre

1. INTRODUCTION

Good energy efficient buildings provide better environments for people using them as well as reducing the impact on the natural environment. Sustainability refers to “the ability of a society, ecosystem, or any such ongoing system to continue functioning into the indefinite future.” as mentioned in the American Institute of Architects (AIA) Handbook. Environmentally conscientious building design is not an option anymore; rather it is becoming a necessity.

The energy is heavily subsidized in Kuwait and there is a significant waste in energy in the form of electric lighting and cooling. Utilizing adequate daylighting into educational buildings, like in the case of Kuwait Autism Centre (KAC), will save energy by the reduction of reliance on electric lighting.

A simulation study of daylighting was conducted on a physical model of a block of classrooms [1]. A series of measurements and photos were taken over an extended period of the day. These measurements were taken, and then results were analyzed. A summary of the results is presented in this paper.

2. THE KUWAIT AUTISM CENTER (KAC) PROJECT

2.1 General description

The KAC project is currently under construction in Meshrif Area, Kuwait. The project will be completed in the beginning of 2008. The cost of the KAC project construction is \$11 Million. It consists of three main components; the administrative building, the gymnasium and swimming pool complex, and the autistic school building. The latter comprises two classroom wings for male and female students, workshops and laboratories building, a simulation house, and staff accommodation studios (Fig.1).

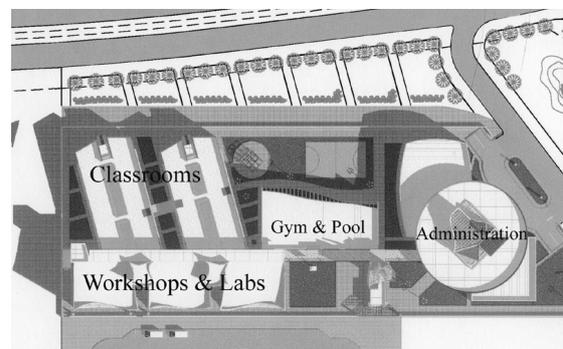


Figure 1: KAC components layout and their shadow.

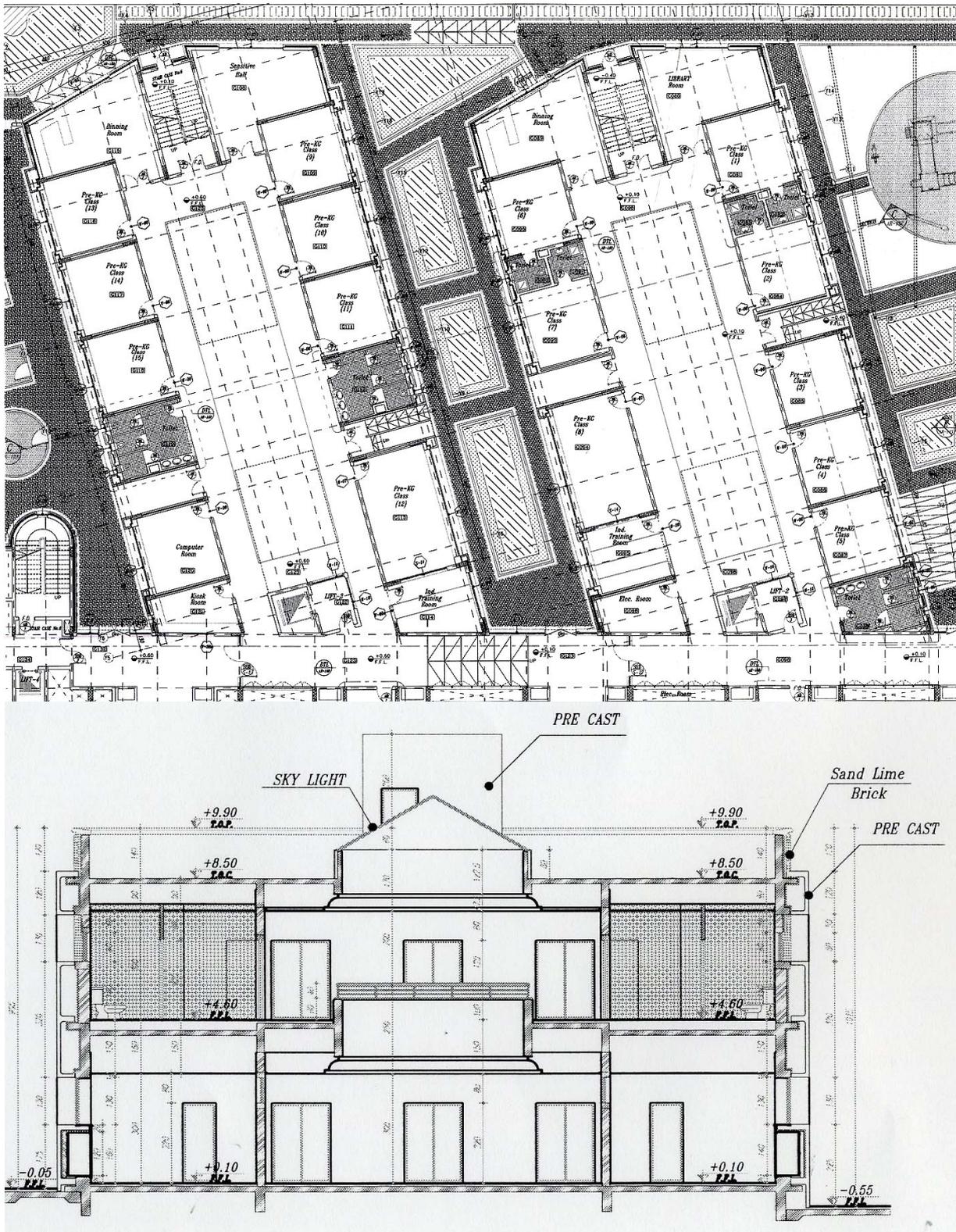


Figure 2: KAC floor plan of two typical classroom wings and a cross section for one of the classroom wings.

The KAC accommodates autistic cases from pre-school age till end of high school. KAC also caters for the needs of older autistic cases through training programs in the simulation house. The focus of this paper is on the study of daylighting in the two

classroom wings (Fig.2). During the development phase of the project, a detailed daylighting study was thoroughly conducted to optimize the building design with the allowance of adequate daylighting.

2.2 Classrooms

Two linear shaped classroom wings two-stories high oriented along the East-West access were proposed where classroom windows are facing either North or South. Each wing is composed of two single-loaded corridors with classrooms on one side and an atrium on the other. This allowed classrooms to be naturally lit from both sides (Fig. 2).

The idea was to provide small depth for the classroom to increase the efficiency of daylighting in terms of daylight penetration. On the other hand, the initial design of classrooms had isolated windows on the North and South façades, which was later modified to continuous windows for the entire length of the classroom. This continuous window strips in classrooms granted uniform daylight distribution. A supplemental strip window is also offered on the classroom façade facing the atrium, with skylight, to provide additional daylight penetration and better daylight distribution. The full benefit from daylighting, both psychological and biological, is achieved when the penetrated daylight into the space is a full spectrum daylight that is achieved in this case by using clear glass whenever daylight is utilized.

2.3 Daylighting and electric lighting integration

The integration of daylighting strategy with the operation of electric lighting in any building is necessary, because energy savings can only be achieved by implementing light controls, sensors and light dimmers for the lighting system of those daylight spaces. This is important because electric lights consume energy when operated as well as produce more waste heat energy than daylighting for the equivalent lighting effect. This heat must be removed in warmer months through ventilation and/or air conditioning. Reductions in cooling loads due to daylighting strategies often enable designers to downsize air conditioning systems and therefore reducing the initial cost of cooling equipment. In the case of KAC project, the daylighting strategy was proposed to provide savings in the energy operating costs as well as less maintenance costs by extending the life of the lamps and luminaires. The total electric lighting power for all of the 28 classrooms is 14kw. Each classroom has 6 luminaires, and each luminaire consists of two 40w fluorescent lamps with 3w electronic ballast.

2.3 Window properties

It is important to use clear glass for daylighting strategies to maintain an undisturbed full spectrum natural light when the biological and psychological benefits are part of its objectives. Scientific research results show that students' performance improve when adequate full spectrum daylighting is provided in classrooms [2]. High performance windows also help to minimize heat gain in warmer months and heat loss in colder months. The minimum requirements of high performance windows should include low u-value glass, insulated frame and window thermal break. It was important to specify such properties for windows of the KAC project to assure proper daylighting strategy.

3. DAYLIGHTING ASSESSMENT

3.1 Objectives

The work of this assessment consists of the review of the all classrooms' areas of the KAC building design in terms of a daylighting strategy. Therefore, this assessment aims to investigate the daylighting potential for the classroom spaces, determine the daylighting strategies for the classroom spaces, and test the daylighting levels in a prototype classroom using physical model experiment representing the fall, winter, spring, and summer seasons.

3.2 Potential for daylighting in classrooms

The design of the KAC, establishes the classrooms' wings oriented on an axis that is only 15 degrees off the east-west axis. This axis orientation was selected based on studies that showed it was an optimum solar orientation for the hot and arid regions [3]. This has developed floor plans with openings that avoided the east and west orientations, and therefore, it minimizes the energy consumption as well as maximizes the potential for the utilization of the daylighting.

Most of the classrooms have square floor plan with a dimension of 5m in width by 5m in length, and the clear height of the floor to the suspended ceiling is 3m. The windows in these classrooms are linear and continuous from wall to wall, and they are bilateral where one side of these windows is facing the corridor with a skylight above it and the opposite side is facing the outside. The outside wall of these classrooms is either on a north or a south orientation. These windows have a sill height of 1.80m from the floor, and the window height is 1.20m, and therefore the head of the window reaches the suspended ceiling directly above it, which is 3m from the floor. The height of the window sill was required by the KAC administration to be 1.80m in order to reduce visual distraction to the autistic students in the classrooms. Moreover, as a recommendation of the daylight design study, a lightshelf was introduced at the height of 1.80m under the window sill of main window strips (Fig.2) to improve the penetration of daylight into the classroom. The design of the windows of the classrooms and the relatively small classroom depth of 5m, considering daylight contribution from both sides of the classrooms, would create a good potential for daylighting contribution.

3.3 Daylighting strategy

The daylighting contribution in the classrooms is bilateral side-daylighting. One side of the each classroom admits daylight from windows facing the outdoor (either oriented south or north) and the other side admits daylight from the side facing the corridor with the skylight. The sill depth of the windows in the side of the classrooms facing the outdoor is 60cm which will work as a lightshelf for the window which is also used as a storage cabinets or bookshelves under the windows. The lightshelf surface is smooth and white to maximize light reflection into the classroom. The light reflectance factor of the lightshelf surface is 90%. This lightshelf is external, when the window in

the classroom is facing the outdoors and oriented south. This means that the glass is recessed to the inside of the classroom to reduce the admittance of the direct solar radiation. The lightshelf surface in the classrooms sloped about 15 degrees to the inside of the classroom to increase the daylight penetration.

The characteristics of the windows that are oriented south double insulated glass with highly reflect top surface horizontal louvers between them. These louvers should always be fully opened to allow for daylight penetration to the classroom by redirecting the daylight to the ceiling, but it should prevent the penetration of direct sunlight to the classroom. However, in the case of the classrooms on the opposite side of the wing, the similar windows in these classrooms are facing the north orientation, and therefore the lightshelf is internal since shading is no longer needed in this orientation. In this case, the glass can be placed to the outside of the wall of classrooms facing the outdoors, and it is a double insulated glass window. The glass type and transmission factor for the windows on both sides of the classrooms is double clear glass with a transmission factor above 80% and a low u-value.

It is important to pay attention to the interior surfaces of the daylight spaces. The success of the daylighting strategy relies on maintaining the required light reflectance factor and the texture of the daylight space interior surfaces. The interior surfaces of the walls of the classrooms should have a smooth white finish texture with a light reflectance factor of not less than 50%. The floor surface of the classroom should have a light reflectance factor of not less than 20%. The ceiling of the classrooms should have a white smooth surface with a light reflectance factor not less than 80%. The ceiling surface is the most important surface among the interior surfaces of daylight classroom surfaces since it reflects the daylight entering from the side windows down towards the floor. Therefore, the porous surface material or similar acoustical ones should be avoided since they would reduce the reflectance factor dramatically resulting in reducing the efficiency of the daylighting strategy.

In order to achieve the savings in the electric energy due to the daylighting strategy, these daylight classrooms should have an electric lighting system that relies on continuous light dimmers with light sensors and light controls that will automatically dim the electric lights when the target illuminance on the working plane is achieved by daylighting. The top surface of the student desks is considered the working plane in the classrooms. The height of the student desks is assumed to be the height of 70cm from the floor. The required target illuminance on the working plane is 500 lux [4].

3.4 Methodology for daylighting assessment

In this study, the daylighting strategy applied to the design of the classrooms of the KAC project was tested. The purpose of this test was to evaluate the illuminance values due to the daylighting strategy in a prototype classroom using physical model experiment. The experiment was conducted to represent the four seasons in Kuwait. These seasons are the fall season (September 21), the winter season

(December 21), the spring season (March 21), and the summer season (June 21). The classrooms are either facing the north or the south side of the wing. Most of the classrooms are identical, except that half of them are in the ground level and the other half are in the first level. The tested physical model represented a section of a classroom wing. This section includes two classrooms on top of each other with a section of the corridor on both levels that includes the atrium in the middle with the skylight above it. The interior reflectance of the physical model surfaces were measured using the light meter and they were 50% for walls, 80% for ceilings, 30% classroom floor, 70% corridor floors, and 40% for outdoor pavement.

The location of the illuminance measurements station points in the classroom has been chosen to be in five different locations. These five station points are then placed where the photo sensors are going to be located for taking the illuminance measurements. These points inside the classroom were placed on the intersection points of a 1.25m by 1.25m grid of the five meters by five meters floor plan. The location of the five points are arranged in a way that the light distribution measurements will be in two orthogonal axes, one is perpendicular to the windows and the other one is parallel to the windows. The illuminances



Figure 3: Simulation experiment tools (physical model of the classrooms showing the classroom's openings, peg chart, Exttech Instruments heavy-duty light meter, photo sensors placed inside the model.)



Figure 4: Physical model of the classrooms showing the opening on the top to simulate the skylight and the atrium below it.

were measured by using five Extech Instruments heavy-duty light meter (Fig.3).

The experiment on the physical model was conducted on the roof of the building 5Kh in Khaldiah Campus of Kuwait University, Kuwait. All the measurements of this experiment were taken every hour from 8am to 4pm on September 21, 2003 that represented the fall season. These measurements were also considered for March 21 that represents the spring season because of the similarities of the solar angles on these dates. Measurements for the other dates of December 21 representing the winter and June 21 representing the summer were taken on the same day (September 21, 2003) by adjusting the model's orientation to meet the correct solar angles that corresponded to the case of December 21 and to the case of June 21. The sky condition on the day of the experiment was clear sky. Measurements were recorded for the lower and upper classrooms, as well as in the case when the classrooms are oriented south and in the other case when the classrooms are oriented north. Therefore, south oriented classrooms recorded measurements for upper classrooms and lower classrooms for the four different seasons. And the same set of measurements were conducted for the north oriented classrooms. The measurements were recorded on every hour starting from 8am and ending at 4pm. Pictures of the physical model were taken during the experiment.

3.5 Data collection

The measurements collected in this experiment are the horizontal illuminance measurements at the working plane. The illuminance measurements of the classrooms for all of the cases representing the four seasons were conducted and recorded. All of the illuminance measurements for the south oriented classrooms were reduced by half (transmission factor is 50%). This reduction factor is to account for the reduction in light penetration due to windows, where 30% is an illuminance reduction due to the use of horizontal louvers, 10% is an illuminance reduction due to the use of the double clear glass with transmission factor of 0.90 for each sheet of glass and 10% is an illuminance reduction for the window frame [5]. On the other hand, the illuminance

measurements taken inside the north oriented classrooms were only reduced 20%. This reduction factor is less than what was used in the south oriented classrooms because the windows are similar except that the clear glass used has a transmission factor of 0.95 for each sheet to increase the north daylight penetration as well as the horizontal louvers were not used in these windows.

3.6 Data analysis

The results of the data measurements of the experiment are shown in Table 1. The results of this study can be analyzed as follows:

Table 1: Minimum illuminance on the working plane in all of the classrooms for all of the seasons (lux).

Classrooms	Minimum illuminance
North	980
South	1,390

- For all of the station points on the working plane, the illuminance measurements in all of the classrooms of the north and south orientations and for all of the four seasons were above the target illuminance of 500 lux (Table 1).

Table 2: Average daily illuminance of all seasons in south and north oriented classrooms for upper and lower floors (lux).

Floor	South Classrooms		North Classrooms	
	Lower	Upper	Lower	Upper
21-Sep/21-March	4,859	4,800	3,037	3,811
21-Jun	3,608	3,824	3,661	3,906
21-Dec	5,961	6,128	2,719	3,602

- The average daily illuminance in the south oriented classrooms were higher than the average daily illuminance in the north oriented classrooms for all of the seasons except for the summer season (June 21) where the average daily illuminance in north oriented classrooms were slightly higher (Table 2).
- In all of the classrooms and in all of the tested situations, the illuminance distributions in the direction along the classrooms (east-west axis) were more uniform than in the direction across the classrooms (south-north).
- The upper and the lower classrooms of both south and north orientations were affected by the skylight contribution from the corridor side.

- The illuminance values and distributions in the upper and the lower classrooms of both south and north orientations were similar.
- The lowest illuminance measurements recorded for the entire south oriented classrooms were the first two morning hours, which are at 8am and at 9am. However it was the opposite in the case of the all of the north oriented classrooms where the last two hours, which are at 3pm and at 4pm, were the lowest illuminance measurements.
- The lowest single illuminance measurement recorded among all of the north oriented classrooms was 980 lux which was recorded at 4pm on June 21; However in the case of the south oriented classrooms, it was 1,390 lux which was recorded at 8am on September 21. Meanwhile, the lowest among these two lowest values mentioned above is almost double the target illuminance required in the classrooms (Table 1).

4. SUMMARY OF RESULTS

The most important analysis about the results of the experiment is that all of the classrooms had illuminance values at least more than double the target level of 500 lux for all of the represented seasons from 8am to 4pm for clear sky conditions. This concludes that the daylighting strategy for the prototype classroom design of the KAC project achieves the required target illuminance throughout the year, and during all school day. The only cases when this is not true are when the sky condition is heavy overcast and when it is raining. This means that the electric lights can be tuned off all of the daytime during the year except partially when the sky is overcast or totally if the school is used at night. Therefore, the calculated annual energy savings due to this daylighting-conscious design will be a minimum of 20,000kwh from electric lighting alone. Additional savings in the building's annual energy costs through shaving the peak load by minimum of 14kw. Moreover, there is an associated savings in the peak load and the annual energy consumption used for cooling load since the heat gain in the classrooms generated by electric lighting is eliminated.

5. CONCLUSION

This paper shows that it is possible to save energy in building operations simply by applying good daylighting strategy integrated with electric lighting. In the case of the KAC project in Kuwait, the daylighting strategy was able to eliminate the need for electric lighting for the whole year during school daytime operation. This project will provide the appropriate daylighting strategies that achieve the quality of light needed to improve student's academic

performance in addition to the energy savings by cutting down on the operation of electric lighting. In a country like Kuwait, attempts to maximize the use of daylighting in buildings will help in reducing the waste in energy sources, as well as creating a balance between the limited sources of energy and the ever-growing demand on power.

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