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Sustainable Design: Daylighting Study of Kuwait Autism Center

This presentation is based on a paper by the presenter and Abdullah Al-Mohaisen.

Building sustainability should start as early as the conceptual architectural design stage. A major part of building sustainability is the environmentally conscious design of spaces in relation to natural elements, such as daylighting. Allowing adequate daylight in buildings improves spatial quality and saves energy required, otherwise, for artificial lighting. In particular places, like classrooms, adequate daylighting becomes a design mandate in addition to an added spatial quality. Remarkable studies have indicated a correlation between the way classrooms are designed and students' performance.

This presentation will discuss a case study of the architectural design of Kuwait Autism Center that adopted, as a major design definer, the provision of adequately lit educational spaces for autistic students. 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 Center. The results were in the form of a set of design recommendations that were implemented in the design development stage. This presentation will show the earlier conceptual design drawings of the educational facilities as well as the final design development of the same facilities after implementing the daylighting design recommendations. It will also summarize these recommendations and explain the daylighting simulation process and analysis that led the architects to proposing them.

Sustainable Design: Daylighting Study of Kuwait Autism Center

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ABSTRACT

Building sustainability should start as early as at the conceptual architectural design stage. A major part of building sustainability is the environmentally conscious design of spaces in relation to natural elements, such as daylighting. Allowing adequate daylight in buildings improves spatial quality and saves energy required, otherwise, for artificial lighting. In particular places, like classrooms, adequate daylighting becomes a design mandate in addition to an added spatial quality. Remarkable studies have indicated a correlation between the way classrooms are designed and students' performance.

This paper discusses a case study of the architectural design of Kuwait Autism Centre 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 Center. The results were in the form of a set of design recommendations that were implemented in the design development stage. This paper presents the earlier conceptual design drawings of the educational facilities as well as the final design development of the same facilities after implementing the daylighting design recommendations. It also summarizes these recommendations and explains the daylighting simulation process and analysis that led the architects to proposing them.

Keywords

Sustainable Architectural Design, Daylighting, Educational Facility Design, Environmentally Conscious Design, Kuwait Autism Centre.

Introduction
Environmentally conscientious design is not an option anymore, rather it is becoming a necessity. The design of a building can be critical to the long-term quality of life for the communities we live in, especially for energy use and environmental impact. 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. "Living in Harmony with the environment has become an essential component of the design of homes and neighborhoods in the third millennium." (Edwards, B. 2000). Establishing daylighting objectives will improve classroom conditions and can help improve student's learning as well as dropping absenteeism rates if the school design includes controlled full spectrum daylight in the classrooms.

In Kuwait, where direct sun penetration into spaces represents a problem rather than an advantage, and therefore, allowing enough daylighting while controlling unwanted sun light infiltration represents a major challenge to architects. In this case, environmentally conscious design has informed the architect to introduce some modifications to the conceptual design that would improve the quality of natural light in internal spaces. "The issue of energy is important to architecture for it represents about 50% of the total energy used throughout the world. Because 25% 0f the world is using 75% of the energy." (De Grey, S. 2000). This is very true in the case of Kuwait, where energy is heavily subsidized and there is no appreciation to waste in energy in the form of artificial lighting. Allowing adequate natural light into educational buildings, like in the case of Kuwait Autism Centre [KAC], will save energy by the reduction of reliance on artificial lighting.

A simulation study of daylighting was conducted on a physical model of a block of classrooms (Al-Mohaisen 2003). This study focuses on the classrooms, because these are the places where students would spend most of their time. A series of measurements and photos were taken over an extended period of the day. These measurements were taken in 21st September, 21st January, 21st March and 21st June to represent the four seasons in Kuwait and then, results were plotted.

Kuwait Autism Centre [KAC] Project General Description
The new premises of the Kuwait Autism Centre [KAC] comprises 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). 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 shown below.

Figure 1: Kuwait Autism Centre components layout and perspective

The initial design proposal for the KAC was the wining entry of a design competition organized by Kuwait Awqaf Public Foundation which was jointly prepared by the Office of Consultation and Career Development (OCCD) at Kuwait University and the Kuwaiti Engineering Group (KEG). During the development phase of the project, a detailed daylighting study was thoroughly conducted to optimize building design with the allowance of adequate daylighting (Al-Mohaisen, 2003). The purpose of this paper is to show the effect of implementing the daylighting study's recommendations on the initial design proposal to arrive at the final design.

Sustainable daylighting design for educational facilities

Scientific research results show that students' performance improve when adequate full spectrum daylighting is provided in classrooms (Patricia et. al, 2000). In a large-scale research in the United States of America, the effects of daylighting on students' performance were studied. The results show a strong correlation between students' performance and daylighting variables such as window size, tint, presence and type of skylight, and the amount of anticipated daylight. Improvements in these variables have positively improved students' performance and behavior in class (Heschong Mahone Group, 1999). This was one of the guiding parameters in the initial design for the KAC. Two linear shaped classroom wings two-stories high oriented along the East-West access were proposed. The idea was to have the longest façades, 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. Those sides were designed to be the longer ones of the classroom layout (Fig. 2).

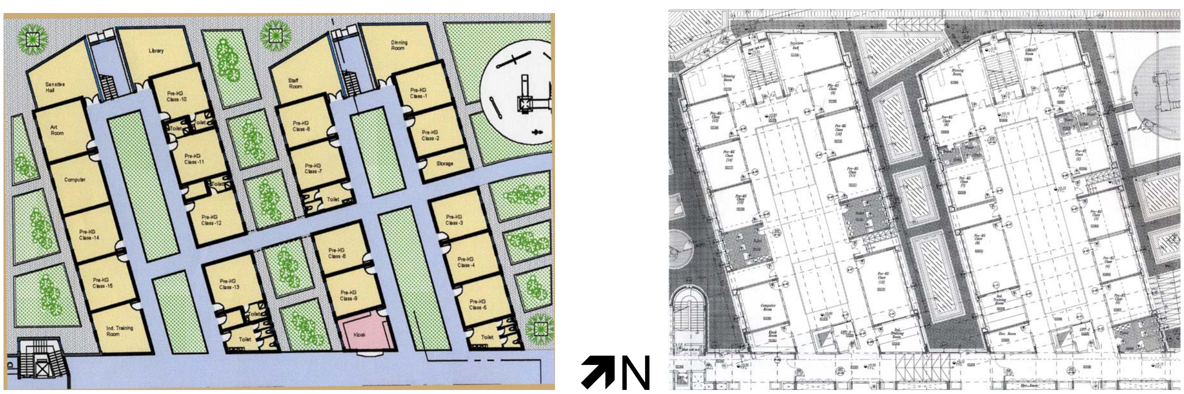

Figure 2: Conceptual and Final design of Classroom wings

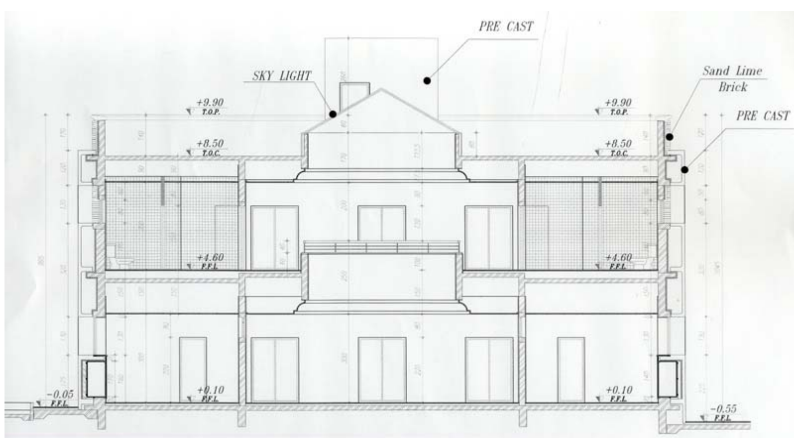

Figure 3: Cross section in a classroom wing

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. Moreover, as a recommendation of the daylight design study, a lightshelf was introduced at the height of 1.60 m under the window sill of main window strips (Fig. 3) to improve the penetration of daylight into the classroom. 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 is achieved when the penetrated daylight into the space is a full spectrum daylight, and this can be done by using clear glass whenever daylight is utilized.

Daylighting and electric lighting integration
Good daylighting design reduces energy consumption as well as creates healthier learning environment that may result in increased attendance and improved grades in the case of school design. When properly designed, windows, clerestories, and roof monitors can provide a large portion of lighting needs without undesirable heat gain or glare. And therefore, electric lights can be turned off or dimmed in daylit spaces when the target illuminance is achieved by daylighting. Energy savings can only be achieved by implementing light controls, sensors and light dimmers for the lighting system of those daylit 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, reducing the initial cost of equipment. Moreover, 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 beak.

OBJECTIVES OF THE STUDY

The main objective of a successful school design is to create a better place to learn. Students spend a lot of their time in schools. The purpose of any school in the world is to educate students. Therefore, the design of school should provide the best environment for the students. Therefore, these schools should be designed for high performance quality schools in terms of focusing on the occupants to perform at their peak. A school design should improve learning by providing better lighting, air quality and acoustics as well as create savings in reduced energy consumption.

The work of this study covers the review of the all classrooms areas of the building design for the KAC in terms of daylighting strategies. Therefore, this study aims to achieve the following objectives:

1. Investigate the daylighting potential for the classroom spaces,

2. Determine the daylighting strategies for the classroom spaces,

3. Test the daylighting levels in a prototype classroom using physical model experiment representing the fall, winter, spring, and summer seasons to assess the classrooms daylighting strategy,

DAYLIGHTING STUDY

Daylighting Potential
The design of the KAC, establishes the classrooms' wings oriented on an axis which is only 15 degrees off the east-west axis. In this study, the orientation of this axis will be called an east-west axis. Therefore, the exterior walls and openings of the classrooms are called either oriented south or north. This has developed floor plans with openings that avoided the east and west orientations. This design characteristic minimizes the energy consumption as well as maximizes the potential for the utilization of the daylighting. Moreover, the floor plans of the classrooms' wings have a large building footprint and small classroom room depth (5 meters is the depth in the classrooms) that maximizes the efficiency of the daylighting contribution to the building. The classrooms are grouped in two almost identical masses. Each mass is a wing of two-story high along the east-west axis with classrooms on both sides facing north and south orientations. Along the east-west axis of the wing is an 8 meters wide corridor with skylight above it. This skylight creates a great potential for daylighting contribution to the corridor as well as to the classrooms through their side windows that are facing this corridor.

Most of the classrooms have square floor plan with a dimension of 5 meters in width by 5 meters in length, and the floor to floor ceiling height is 4 meters. However, the clear height of the floor to the suspended ceiling is 3 meters, because the height of the suspended ceiling is one meter. 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 1.80 meter from the floor, and the window height is 1.20 meter, and therefore the head of the window reaches the suspended ceiling directly above it, which is 3 meters from the floor. The design of the windows of the classrooms and the relatively small classroom depth of 5 meters, considering daylight contribution from both sides of the classrooms, would create a good potential for daylighting contribution. The lightshelf surface in the classrooms should be sloped about 15 degrees to the inside of the classroom.

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 60 cm 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 should be as smooth as possible and as white as possible to maximize light reflection into the classroom. The light reflectance factor of the lightshelf surface should not be less than 90%. This lightshelf should be external, when the window in the classroom is facing the outdoors and oriented south. This means that the glass should be recessed to the inside of the classroom to reduce the admittance of the direct solar radiation, and therefore causing heat gain. 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 are recommended are double glass with white-color 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 should be 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 glass window but without horizontal louvers. The glass type and transmission factor for the windows on both sides of the classrooms is double clear glass with a transmission factor above 90% and a low u-value.

It is important to pay attention to the interior surfaces of the daylit spaces. The success of the daylighting strategy relies on maintaining the required light reflectance factor and the texture of the daylit 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 daylit 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 daylit 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 70 cm from the floor. The required target illuminance on the working plane is 500 lux (Robbins, 1986).

ASESSMENT OF THE DAYLIGHTING STRATEGY FOR THE PROTOTYPE CLASSROOM

Methodology

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 illuminances 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 2 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 as follows:

Walls and Ceilings	80%
Classroom floors	30%
Corridor floors	70%
Pavement floor (outdoors)	40%

The location of the points of illuminance measurements in the classroom has been chosen to be in five different locations. These five locations 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 1.25 meter by 1.25 meter 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 were measured in this experiment by using five Extech Instruments heavy duty light meter as shown in (Fig. 4).

Figure 4: Simulation experiment tools used; physical model of the classrooms, Extech Instruments heavy-duty light meter, peg chart used for solar angles and the photo sensors placed inside the model.

The experiment on the physical model was conducted on the roof of the building 5KH in Khaldia Campus of Kuwait University. All the measurements of this experiment were taken on September 21, 2003 that represented the fall season, and also was considered for March 21 that represent 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 a clear sky (a cloudless 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 8.00 AM and ending at 4 PM. Pictures of the physical model were taken during the experiment.

Data Collection
The measurements collected in this experiment are the horizontal illuminance at the working plane. The illuminance of the classrooms' measurements for all of the cases representing the four seasons were conducted and recorded. All the illuminance measurements taken inside the south oriented classrooms were reduced 50%, and therefore the values were reduced to half. 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 white color horizontal louvers, 10% is an illuminance reduction due to the use of the double clear glass with transmission factor of 0.95 for each sheet of glass and 10% is an illuminance reduction for the window frame (Stein 1995). 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 horizontal louvers were not used in these windows.

Data Analysis
The results of the final data measurements of the experiment were shown below in Table 1. The results of this study can be analyzed as follows:

1. For all of the selected station points on the working plane in the classrooms, the illuminance in all of the classrooms of the north and south orientations and for all of the four seasons was above the target illuminance of 500 lux.

2. The average illuminance in the south oriented classrooms were higher than the illuminance in the north oriented classrooms for all of the season measurements except for the summer season (June 21) where the illuminance in north oriented classrooms were slightly higher.

3. 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).

4. The Upper and the lower classrooms of both south and north orientations were affected by the skylight contribution from the corridor side.

5. The illuminance values and distributions in the Upper and the lower classrooms of both south and north orientations were similar.

6. The lowest illuminance measurements recorded for all of the north oriented classrooms were the first two morning hours which are at 8 AM and at 9 AM, However it was the opposite in the case of the all of the south oriented classrooms where the last two hours which are at 3 PM and at 4 PM were the lowest illuminance measurements.

7. The lowest single illuminance measurement recorded among all of the north oriented classrooms was 980 lux which was recorded at 4 PM on June 21; However in the case of the south oriented classrooms, it was 1,390 lux which was recorded at 8 AM on September 21. Meanwhile, the lowest among these two lowest values mentioned above is almost double the target illuminance required in the classrooms.

8. The highest single illuminance measurement recorded among all of the north oriented classrooms was 8,240 lux which was recorded at 8 AM on June 21; However in the case of the south oriented classrooms, it was 8,000 lux which was recorded at 12 noon on December 21.

9. The average illuminance for all the seasons in the south oriented classrooms is 4,075 lux, and the average illuminance in the north oriented classrooms is 3,544 lux (see the table below).

10. The average illuminance for all the seasons in the south oriented classrooms is higher than the average illuminance in the north oriented classrooms.

Classrooms	**Min**	**Max**	**Average**
Oriented north	**980**	**8,240**	**3,544**
Oriented south	**1,390**	**8,000**	**4,075**

Table 1: Minimum, maximum and average illuminance of all seasons in south and north oriented classrooms (lux).

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 which are the fall/spring, winter and summer during the time from 8 AM to 4 PM for clear sky conditions. This concludes that the daylighting strategy for the prototype classroom design of the Kuwait Autism Center project achieves the required target illuminance throughout the year, and during all school day. The only cases when this not true is when the sky condition is overcast and when it is raining. This means that the electric lights can be tuned off all the time except partially when the sky is overcast or totally if the school is used at night.

CONCLUSION
The KAC Project is one of the few projects in Kuwait to pay careful attention to providing a high performance luminous interior environment. From the conceptual design right through to the final design, the provision of adequate daylighting was the prime target of the design team. The team was helped to achieve this goal by the detailed daylighting study conducted by specialists during project development. This project will provide the appropriate daylighting strategies that achieve the quality of light needed to improve student's academic performance as well as the energy savings by cutting down on the operation of electric lighting. In addition, the KAC will use the state-of-the-art technology in electric lighting and controls that will assure the quality of light output and operation. This presents a serious endeavor to apply sustainable design strategies for daylighting. In a country like Kuwait, where electricity cannot continue to be subsidized by the government, attempts to maximize the use of daylight 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. And that, to some extent, is sustainable design.

REFERENCES

Al-Mohaisen, A. 2003
A DAYLIGHTING AND ELECTRIC LIGHTING STUDY FOR THE KUWAIT AUTISM CENTER PROJECT, *A technical report submitted to Kuwait Engineering Consultants (KEG), Kuwait*: Office of Consultation and Career Development (OCCD), College of Engineering and Petroleum-Kuwait University.

De Grey, S. 2000
ECOLOGY IN ARCHITECTURE, *Sustainable Housing: Principles & Practice*, London: E & F Spon.

Edwards, B. 2000
INTRODUCTION: SUSTAINABLE HOUSING, *Sustainable Housing: Principles & Practice*, London: E & F Spon.

Heschong Mahone Group, 1999
DAYLIGHTING IN SCHOOLS: AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN DAYLIGHTING AND HUMAN PERFORMANCE, *The Pacific Gas and Electric Company on behalf of the California Board for Energy Efficiency Third Party Program*, Fair Oaks, CA.

Patricia P., Conway S. and Epstein K. 2000
DAYLIGHTING IN SCHOOLS: IMPROVING STUDENT PERFORMANCE AND HEALTH AT A PRICE SCHOLS CAN AFFORD, National Renewable Energy Laboratory (NREL): Colorado.

Robbins, C. L., 1986
DAYLIGHTING: DESIGN AND ANALYSIS. Van Nostrand Reinhold Company: New York.

Stein, B. 1995
MECHANICAL AND ELECTRICAL EQUIPMENT FOR BUILDINGS, Ninth Edition, John Wiley and Sons, Inc.: New York.