
LIGHTING A MUSEUM

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Abstract – This paper presents several daylighting strategies to carefully control the lighting levels in the Kuwait National Museum located in Kuwait City. The museum collection consists of about 35,000 objects, including ancient manuscripts, wood, ivory, metal, glass, jewelry, wools, silks, leather, cotton, carpets, textiles and tapestries. The following are the building envelope components proposed to control and filter the entrance of daylighting through the several large existing sidelight windows: (1) exterior shading devices, (2) dynamic louvers, (3) switchable glazing, and (4) motorized shading. The daylighting systems were evaluated through a series of computer-assisted ray-tracing studies, and iteratively refined to respond to a wide range of solar positions and outdoor conditions. The RADIANCE ray-tracing lighting software was used to model, simulate and analyze the daylight performance of the different daylighting systems. Results showed that the proposed daylighting systems can achieve the desired interior illuminance levels for the display of the different artifacts. Sunlight was can be intercepted at all times from all sidelight windows. During closed hours around noon, the daylighting systems shut completely off from the exterior daylight helping to preserve the most sensitive artifacts, i.e. manuscripts and textiles. Lighting will be supplemented by electric lighting at further locations from the sidelight windows and during nighttime hours.

1. INTRODUCTION

The Kuwait National Museum (KNM) was designed by the French architect Michel Ecochard in the 1950s, but actually built in the 1970s. The museum houses the collections of the Dar al-Athar al-Islamiyyah Museum (comprising the al-Sabah Collection) in the Mathaf al-Kuwait al-Watani in Kuwait City. The whole collection comprises more than 35,000 objects, with objects from all over the Islamic world that includes manuscripts, wood, ivory, metal, glass, jewelry, wools, silks, leather, cotton, carpets, textiles and tapestries, and any kind of object which relates to the scientific and practical life of Muslims.

The original museum complex consisted of four buildings around a central open courtyard. The al-Sabah collection was exhibited mainly in Building 3 and 4. During the Iraqi invasion between August 1990 and February 1991, the KNM was looted and burnt. Building 3 suffered severe damage mostly due to fire, while Building 4 had less damage, mainly due to bad maintenance. In 2002, UNESCO commissioned a team of experts to study the rehabilitation of Buildings 3 and 4 of the KNM (Beltrán 2002a), as well as the construction of new buildings: 2, 6, 7, 8, 9 and 10 (Figure 1).

2. EXISTING CONDITIONS

2.1 Courtyard
The courtyard provides access to Buildings 3 and 4, and it is partially shaded by a series of hanging elements. The amount of shade in the courtyard is approximately 40% (as depicted in Figure 2). There is a huge difference in light levels between shaded and unshaded areas. Photometric measurements taken under clear sky conditions on May 28, 2002 at 9:00 AM, at the center of the courtyard shows that the illuminance level in unshaded areas varied between 78,000 to 85,000 lux, while in shaded areas varied between 7,500 to 9,000 lux (approx. 90% less than unshaded areas). At the outdoor area between Buildings 1 and 3, (sunlight area without obstructions), the illuminance level reached 110,000 lux. These high illuminance levels of exterior spaces adjacent to the museum entrance and sidelight windows needed to be reduced gradually through the creation of shaded transitional spaces that allow visitors’ vision to adjust slowly to the museum’s low illuminance levels.
2.2 Building 3

Building 3 is approximately 70 m in length, 28 m in width and 14 m in height, encompasses a building volume of approximately 27,000 m³. Ramps access the ceiling levels vertically at different heights. The primary distinctions are between the ground floor, the upper floors and a mezzanine.

Building 3 has SE and NW large openings with only the large horizontal and vertical parasols (Figure 3). The original small shading devices designed by Ecochard were destroyed. Notice in Figure 3 the scattered shaded areas on both windows planes provided by the courtyard canopy.

2.3 Building 4

Buildings 4 is approximately 50 m in length, 28 m in width and 14 m in height. The overall appearance of this building is similar to the other original three buildings (1, 3 and 8) of the museum complex. This building has its original complete set of fenestration system (glazing and shading devices) in the NE and SW facades (Figure 4).

The interior of both Buildings 3 and 4 is a large open space developed in multiple platforms, at four different levels linked through different sets of ramps. There are no transitional spaces between the exterior and interior spaces to let visitors adapt to the low interior light levels. Sunlight penetration is more extensive in Building 3 than in Building 4, because of the lack of glazing and smaller shading devices. Sun rays inundate many vertical surfaces and platforms with harmful UV light. Direct sunlight hits the SE and NW large windows of Building 3, and the NE and SW large windows of Building 4, especially during the early morning and late afternoon hours. Figure 5 shows different views along the NW side of Building 3. The sun at this time is almost in front of the window opening, and can penetrate deep into the space. Sunlight patches are not only on the floor, but also on the side and back walls.

Even though Building 4 has the original glazing and shading devices in both large sidelight windows, it also lets pass through its sidelight windows harmful sunlight rays. Figure 6 shows the sunlight penetration through the SW windows mostly between 2:00 and 5:00 PM from August to April.
Figure 6. Fish-eye view of SW side of Building 4 with sun path showing the hours of sunlight penetration at the center of space.

Buildings 3 and 4 are connected through a bridge (at level +5.64) that has several strip windows along both sides, facing the SE and NW orientations and two rows of skylights on the roof (see Figure 7). Photometric measurements along the bridge around 5 PM on May 27 showed very high light levels under direct sun. Horizontal illuminance levels along the bridge varied from 200 to 1,500 lux, while luminance measurements through the windows facing west towards the Gulf were extremely high around 236,000 cd/m². The windows along the bridge have no sun control devices and the excessive amount of apertures provides too much light and heat to this transitional space.

The normal operating hours of this museum are from 9:00 AM to 1:00 PM, and from 5:00 PM to 8:00 PM year-round. Due to the high illuminance of the site and object conservation needs, special care was taken to control and filter daylight during all daytime hours throughout the year in all interior spaces.

3. DESIGN STRATEGIES

Museum lighting must balance the exhibition and conservation needs and enrich the museum experience. The following section includes the design strategies to ameliorate the existing lighting conditions of the exterior spaces, building envelope and interior spaces of Buildings 3 and 4.

3.1 Exterior Spaces

The environmental conditions of exterior spaces around the museum needed to be treated as transitional areas where light levels is gradually adjusted to the museum exhibition light levels during daytime as well as nighttime hours. By improving the lighting and thermal conditions of these areas we are adding more opportunities for people to remain in these spaces, and to adapt to the interior environmental conditions of the museum. The following changes will be incorporated:

- Add more shaded area to parking lots, paths, and courtyard.
- Extend the roof area of the courtyard to overlap the buildings and bridges.
- Add moisture to the air, the same as in some Kuwaiti outdoor cafes.
- Add more vegetation and water elements (i.e. water ponds, and fountains).
- Add more outdoor sitting areas.
- Decrease concrete paving areas to reduce long-wave heat radiation.

The lighting elements that will be added to the exterior spaces:

- Additional hanging elements to the courtyard canopy as light reflectors of natural and artificial lighting.
- Prismatic films or panels to create some special patterns on floors.
- Theatrical lighting for night time special events where the courtyard canopy will be used as a projection screen, i.e. theatrical light can project patterns related to Islamic art or some educational presentations for the community that could take place in this setting.
- Lighting fixtures integrated to landscape themes and designs.

3.2 Building Envelope

The sidelight windows in Building 3 and 4 represent a problem for the museum displays due to their lack of daylight control. Sidelight windows provide non-uniform light distribution throughout the space with high illumination levels in areas adjacent to the window plane. Photometric measurements of horizontal illuminance levels taken near the sidelight windows of Building 3 were between 1,200 to 1,500 lux, while towards the center of the building light levels were much lower, around 50 lux. Vertical illuminance measurements in interior walls facing the windows, under direct sunlight, were as high as 4000 lux (see Figure 5).

Preliminary computer simulation of buildings 3 and 4 showed that many interior walls adjacent or facing the window planes were under direct sunlight during many museum operating hours. These sunlit vertical planes
could not display any artifacts without a carefully designed sun control system that prevent the entry of harmful UV light, and reduce the high lighting levels. The combination of several daylighted control strategies allowed to reach the light levels required by each museum artifact with the help of a central computer system that continuously be monitoring and adjusting the light levels of each display. Two alternate glazing systems solutions were proposed to control the entrance of the harmful ultraviolet (UV) light, and infrared (IR) radiation to the interior spaces (Beltrán 2002b). The two glazing systems combine several layers of glass, coatings, and motorized shades to control the interior lighting. The selected glazing system consists of the following components:

- Self-Cleaning Glass Coating
- Impact and Fire Resistance Glazing
- Low-E Coating
- Switchable glazing (SPD)
- Dynamic louvers
- Motorized Roll-up Shading

Only the last three components were included in the daylighting analysis to assess their effect in the exhibit areas with sidelight windows. The switchable glazing (d) SPD (Suspended Particle Device) allows a range of transparency where light transmission can be rapidly varied to any degree desired depending upon the voltage applied. The visible transmittance (Tvis) can vary from 88% to 9%. The switchable glazing is used in combination with a dark tinted glass with Tvis of 3.8%. The dynamic louvers (e) Glass Louvre is an electrically operated solar control system that uses glass mounted louvers to intercept the entrance of sunlight into the interior spaces providing full control of interior light levels. Louvers are made of white matte coating laminated onto the top of a glass panel. The motorized shading system (f) Electroshade rolls up into the ceiling pocketing and disappears from view.

3.3 Interior Spaces

The design of the museum building envelope should find a balance between the aesthetics and the requirements determined by the architect, the conservationist and the client; and the use of interior spaces. One of the major concerns in the design of a successful museum is to provide adequate light levels for the preservation of the museum objects as well as to enhance the view of them. Daylight, due to its changing nature, represents a challenge for the design of a successful window system; therefore, special care should be taken to the design of each window in all the KNM buildings. The selected daylighting system is flexible enough to provide a wide range of interior lighting levels for the different window orientations, outdoor conditions, and lighting requirements of each museum artifact, as well as to exclude daylight entirely when the museum is closed to the public or when its presence is not desired.

The selected glazing system for the sidelight windows of Building 3 and 4 were analyzed using the RADIANCE ray-tracing lighting simulation program to predict the interior lighting levels with each system.

Figure 8. Interior spaces of the SE side of Building 3 with different glazing systems: (top) existing conditions, (center) switchable glazing, and (bottom) switchable glazing with dynamic louvers and motorized shading, at 9:00 AM, December 21.

Figure 8 depicts the interior illumination of three different facade systems for the SE side of Building 3 on December 21 at 9:00 AM when the sun is at a low angle in front of the window. The three facade systems presented here are: (a) existing building conditions (no glass, only original shading devices), (b) switchable glazing at a darkened stage in combination with the outside tinted glass layer (Tvis 0.3%), and (c) all the components of b in combination with the dynamic louvers in closed position and screens. Notice in Figure 8-center how the space is darkened when using the switchable glazing (at its darkest stage), and the darkest conditions when the switchable glazing is combined with the dynamic louvers and screens (Figure 8-bottom). These lighting simulations did not include the hanging elements of the courtyard canopy which will reduce more the total amount of light entering through the sidelight window.

Figure 9 shows the illuminance level of the above three facade systems (December 21, at 9:00 AM). The existing conditions (top) introduce more than 5000 lux on the floor plane; while with the switchable glazing at its
darkest stage (center) light levels are reduced to 1000-1200 lux. When combined the switchable glazing with the louvers and screens (bottom), light levels reach as low as 25-40 lux throughout the space. The glazing system offers a wide range of light level control ranging from 3000 lux (switchable glazing clear, dynamic louvers open and screens rolled up) to 25 lux (switchable glazing darkened, dynamic louvers closed and screens rolled down).

The daylighting systems will be controlled by a computer system that will be linked to the electrical lighting control system of the museum to control the exact amount of lighting levels as well as its annual cumulative illuminance (annual lux-hours) that each artifact requires.

The envelope design of the bridges will incorporate the above strategies to control the ever-changing natural light. The bridges require sunlight control in the mornings at the Eastern side and in the afternoons at the Western side. Bridges, in addition to serve as building connectors and transitional spaces, can visually connect with the exterior through deep view windows created for visitors who intentionally want to stop to view the surroundings.

4. RESULTS AND CONCLUSIONS

Results showed that the proposed daylighting systems can achieve the desired interior illuminance levels for the display of the different museum artifacts. Sunlight can be intercepted at all times from all sidelight windows. During closed hours around noon, the daylighting systems can shut completely off from the exterior daylight to preserve the most sensitive artifacts, i.e. manuscripts and textiles. Lighting will be supplemented by electric lighting at further locations from the sidelight windows and during nighttime hours.

This paper presents a summary of the current state of the lighting design of the KNM project. The next phase of the lighting design will examine in more detail the illuminance levels at all display areas, cumulative distribution of illuminance (number of hours over the maximum exposure by displayed object), louvers and glass transmittance as a function of sun altitudes by window orientation, luminance distribution, eye adaptation, glare evaluation, interaction of artificial lighting with natural light, etc. New buildings will be added to the complex such as a new entrance building with café and amphitheatre, a library, and a building for conservation, research, storage, working areas and offices.

5. ACKNOWLEDGMENTS

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REFERENCES

