Scholars Journal of Engineering and Technology (SJET) **ISSN 2321-435X (Online)**
Sch. J. Eng. Tech., 2014; 2(3B):388-391 **ISSN 2347-9523 (Print)**
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www.saspublisher.com

Review Article

Discussion on Natural Daylighting and Energy-efficient Lighting Technology for Natatorium

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Abstract: Lighting consumes one fifth to one third of the total energy consumed by the operation of a natatorium, therefore, efficient daylighting plays an important role in energy efficiency of a natatorium as a whole. There are two forms of lighting for natatoria: natural daylighting and artificial lighting. During normal swimming competitions or under normal conditions of use, natural daylighting, in combination with energy-efficient artificial lighting, should be used as much as possible to save energy and reduce energy consumption.
Keywords: Natural daylighting; Energy efficiency; Artificial lighting

INTRODUCTION

Natural Daylighting and Its Characteristics

Reasonable natural daylighting is essential whether from human psychological and physiological factors or the maximization of the energy-saving effect [1]. The daylighting interfaces of building envelopes can control the intensity of interior light to achieve an ideal lighting effect and effectively prevent glare [2]. Generally, the daylighting design of natatoria is required to provide adequate and uniform illumination, soft light, avoid strong shadow as well as pay special attention to glare control. In order to reduce glare, the daylighting areas at the sides of the swimming pools and above the diving pools should be arranged outside the 20 degrees so as to mitigate the impact of glare on athletes and audiences. Figure 1 is a diagram of glare avoidance of natural light for a swimming hall.

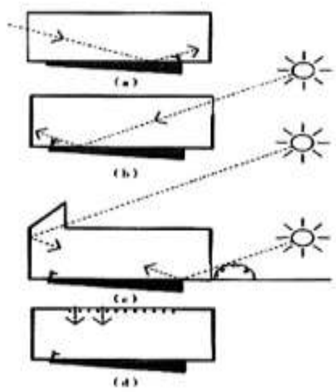

Fig-1: Glare Analysis of Natural Daylighting for a Swimming Hall There is reflection from the water surface in (a) and (b), but not in (c); and in (d) the natural light penetrating through the skylight above

Natatoria have a long span and thus have low illumination within the swimming halls, and daylighting through traditional side windows is difficult to meet the illumination requirement. Therefore, large-area side windows, top roof daylighting, roof daylighting through transmittance and diffusion, openable roof daylighting and other modes are used in natatorium daylighting. Several daylighting modes can be used together in design according to the actual conditions to achieve uniform and balanced daylighting effect.

Daylighting through side windows

Daylighting through side windows is mainly used in small- and medium-sized natatoria or professional natatoria, because the small number of seats favors the opening of side windows. However, large-area side windows can easily produce glare on the water surface and thus catch the audiences' eye and divert their attention. Therefore, side windows should not be large when there are stands on both sides of the swimming pool. Moreover, strong penetration of light in the natatorium can lead to bright stand area and dark competition area, which exerts an impact on the competition and the audiences, but can be mitigated by using, for example, shade cloth.

Top roof daylighting

Large-sized natatoria usually have a long span, and to guarantee natural daylighting and avoid glare, roof daylighting is the most effective daylighting mode. Openable skylights for natural light and ventilation can be added at the ridge, with indoor shade cloth which can be closed during competition and opened after competition. The maximization of natural light and the reduction of artificial lighting within venues will greatly reduce the lighting energy consumption by their operation after competition. Considering the overall energy-saving effect, the area of the transparent part of the natatorium roof should not exceed 20% of the total roof area. There are three main top roof daylighting modes. One is to install daylighting panels at the openings left on the roof board; another is to alter the local structural interface where a skylight is put in; the third is to put in a skylight where similar or different structures connect.

Daylighting through roof joints

Natural daylighting through roof joints requires a building to have a combined roof, and daylighting is realized through the roof joints. A foreign example: glass skylights are installed between the prestressed reinforced arch ribs of Montreal's Central Natatorium, Canada to introduce natural light into the competition hall (Figure 2).

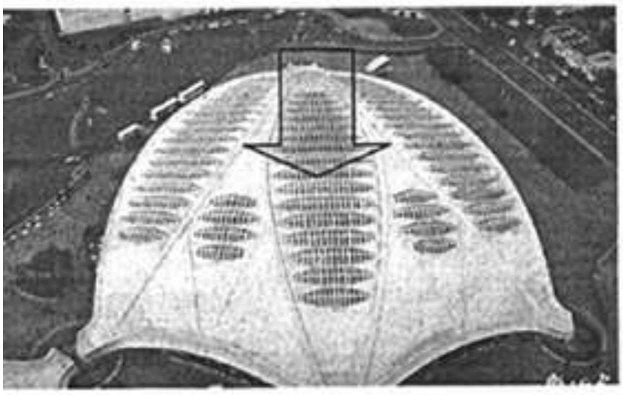

Fig- 2: Daylighting Skylight of Montreal's Natatorium, Canada

Natural daylighting through openable roofs

For the south with hot summer and cold winter and the areas with hot summer and warm winter, natatoria can close their roofs in winter, and serve as unroofed venues by opening them in spring and summer to obtain natural light.

Natural daylighting through membrane structures

The application of membrane structures provides more space for natural daylighting of natatoria and makes possible the all-weather natural light inside the natatoria. The membrane allows light to transmit into a building, become soft and have uniform intensity. Therefore, there is no sharp contrast between the sunlit side and the shadow side and thus human eyes are comfortable, and there is also no glare from the water surface, which reduces the impact of dazzling bright light on athletes' eyes.

For example, the National Aquatics Center, colloquially known as the "Water Cube" (Figure 3), adopts a fully enclosed design and the roof and wall material is ETFE membrane, which guarantees the penetration of 90% natural light into the venue, about 10 hours every day. Therefore, the daylighting of this venue is not affected and lights need not to be turned on for most of the competition, which greatly reduces lighting energy consumption by 29.4%, 627MWh each year. In addition, the inner space of the Water Cube has different functions, and luminosity and light transmittance can be adjusted to meet the daylighting requirements by adding silver-plated points of different density to and changing the membrane layers (the light transmittance of visible light for single ETFE layer is 94%) of the façade and roof air pillows.

Fig-3: Interior of Water Cube

ENERGY-EFFICIENT ARTIFICIAL LIGHTING TECHNOLOGY FOR NATATORIUM

Artificial lighting is used in the natatoria when natural daylighting cannot meet the indoor light requirement. The analysis of the daylighting requirements of natatoria shows that natural daylighting can be used primarily for general training programs, while artificial lighting is usually used when formal sports competitions are held to achieve standard competition illumination because they have high requirements for light quality and quantity. The power consumption by lighting is also a major part of the daily operating costs of natatoria.

CLASSIFICATION OF ARTIFICIAL LIGHTING IN NATATORIUM

Artificial lighting in natatoria is mainly classified into competition lighting, underwater lighting, general lighting and sign lighting. Other lighting systems mainly include emergency lights, under lights, TV lighting, etc.

Competition lighting is mainly used to create good visual conditions for athletes. The sports lighting control system is used for the competition area, and the scene lighting control system is used for other indoor public space and landscape lighting, which aims to save electricity by setting up a multi-scene mode according to different needs, different time frames and the natural light environment. Underwater lighting is set up to improve visual perception and underwater camera shooting. It is a special lighting and has high requirements for the lighting equipment, such as strong corrosion resistance, good sealing property and high centralized illumination. General lighting and sign lighting refer to the lighting set up to meet the illumination requirements of different competitions, training and opening to visitors, such as the emergency or escape lighting, sign lighting at the stand area, which is required to be arranged reasonably by taking into consideration the function layout, evacuation of people and competition requirements.

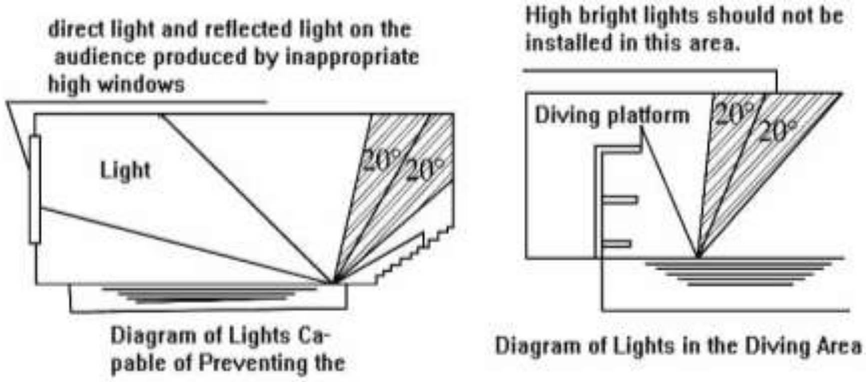

Fig-4: Location Diagram of Glare Avoidance for Artificial Lighting in Natatoria

ENERGY-EFFICIENT LIGHTING TECHNOLOGY FOR NATATORIUM [3-4]

(1) Layout and control of lights

Lights on the suspended ceiling of the swimming hall are inclined to be arranged in rows, and their height and angle relative to the water surface should also be considered carefully. The lights flanking the diving pool should have light screens, and it is inadvisable to install lights at the back of the diving platform, otherwise glare will be produced (Figure 4). To avoid strong reflection from the water surface of the swimming pool and its influence on athletes' visual judgment, the lights in the competition area often cast light sideways. And vertical light screens should also be installed for the lights flanking the diving competition pool in order to mitigate the glare within the range of their visibility when athletes flip in the air. The color and color rendering property of the light source should also meet the visual requirements of athletes and audiences and those of TV cameras and watching.

(2) Selection of energy-efficient lights

The selection of electric light sources for natatoria is mainly to ensure safety and save energy. From the perspective of safety, natatoria have high temperature and humidity and, highly acidic vapor in the air due to the chemical hypochloric acid used for disinfection in the swimming pool, which have a direct corrosive effect on the lights. Therefore, they should be fully enclosed energy-efficient lights which are moisture-proof and corrosion resistant. From the perspective of energy efficiency, the local capacitance competition system is used to improve the power of lights, and high quality electric rectifiers or energy-efficient magnetic ballasts are used to reduce electricity consumption and pollution to the power grid. The commonly used, most efficient lights are metal halide lights or high pressure sodium lights. The former has a high lighting effect, good color rendering effect, low attenuation, long life and small lamp body, and is about half of the volume of the latter. Meanwhile, when selecting lights, we should also avoid glare by applying special treatment to the reflective surface of lights to limit their surface brightness and generate diffuse reflection so as to soften the light. The shielding angle of lights should also be increased and grids added at their outlets to reduce their outlet brightness.

New energy-efficient lighting technology (LED)

LED lights are energy-efficient lights, and have already been widely used in many large-scale public buildings at home and abroad [5]. For instance, the "Water Cube" built for the Beijing Olympic Games adopts this latest landscape lighting technology in its façades (Figure 5). RGB-type LED lights are installed within the air pillows, and acting as an independent illuminated unit, each air pillow uses a set of LED lights with different numbers. Under the huge systemic control, the five facades employ 37000 sets of customized LED lights, which are installed between the double-layered ETFE membranes. The main color of the basic scene mode is water blue with appropriate brightness. The combination of computer, network communication, image processing and other techniques provides a changing scene mode and, the double effects—lighting and energy efficiency are also achieved.

Fig-5: Lighting Effect of the Water Cube at Night

CONCLUSION

Natural light creates the most comfortable, amiable, healthy and beautiful indoor light environment, and enables those swimming in the natatoria to fulfill their wishes to return to nature; while artificial lighting, as a supplement to natural daylighting, is more accurate, technical and operable. Through the lighting control system, natatoria can enjoy a multi-scene mode according to different needs, different time frames and the natural light environment so as to reduce electricity consumption.

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