Optik 127 (2016) 1213–1216

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Lighting design of underground parking with tubular daylighting devices and LEDs

Simei Ji, Guanying Cao*, Jinghui Zhang, Fangnan Yu, Desheng Li, Jingjie Yu

Research Institute of Photonics, Dalian Polytechnic University, Dalian 116034, China

ARTICLE INFO

Article history:
Received 31 January 2015
Accepted 29 October 2015

Keywords:
Lighting design
Tubular daylighting device
LED lamps
Energy saving

ABSTRACT

In the paper, we made full use of daylight and electrical artificial light sources to achieve energy saving and comfortable lighting environment. Field investigation of the lighting design of one underground parking in Dalian Nationalities University of China was investigated and improved by simulation. The tubular daylighting devices and LEDs were used to the lighting design of the underground parking. The light distribution curve of the tubular daylighting device was simulated by the software of Tracepro and put into DIAlux for lighting design with LEDs. The simulation results show that the hybrid lighting system with daylight and LEDs meet the lighting standard. Annual energy savings of underground parking is 60.4%.

1. Introduction

In recent years, the number of the underground parking in building and commercial center is increasing rapidly. More advanced and sophisticated equipment makes energy consumption increases. As example, an underground parking installed 1000 lamps. Lighting energy consumption can reach 350,000 kWH or more each year. According to statistical data, there is an invalid lighting alone accounts for around 60%. Underground parking is a special place that should be uninterrupted lighting. Due to the large-scale, complex structure, narrow space, daylight can't directly enter the underground space. Therefore, daylight for illumination through a new lighting system is meaningful.

Tubular daylighting device is a novel way of using daylight. Currently this approach has attracted much attention all over the world. Tubular daylighting device collects enough daylight to illuminate without any electricity. It is a good choice for some places without windows to transmit daylight. Nowadays, the applications of tubular daylighting device are widely, such as rooms without windows, tunnel, underground passages, corridors and so on [1].

In the paper, we focus on the application of tubular daylighting device. The hybrid of daylight and artificial light sources is applied to the lighting design of the underground parking in Dalian Nationalities University to achieve energy saving and comfortable lighting environment. Tubular daylighting device can't be simulated by DIAlux without light distribution curve. Therefore, the light distribution curves of tubular daylighting device were simulated by the software of Tracepro and put into DIAlux for lighting design with LEDs.

2. The field investigation of the underground parking

For the lighting design of underground parking, we selected a real underground parking for a field investigation. Dalian Nationalities University (DNU) is located in Dalian, the famous coastal city of China. There are two campuses in DNU, the Development Zone Campus and the Jinshitan Campus, with a total area of 775,900 m^2. The build-up area is 488,800 m^2, among which the teaching and administration occupies 282,300 m^2.

The lighting design of one underground parking in Dalian Nationalities University was investigated in suit. The underground parking is located on the center of the ground floor of the teaching building under the grass land where can be installed tubular daylighting devices. The area of the underground parking is about 2088 m^2. The actual lamp arrangement is shown in Fig. 1. The fluorescent lamps with 36 W are arranged for the lighting in the underground parking. The light distribution is not uniform due to the damage of some lamps. The illumination range of the carriageway is 30–60 lx. The illumination range of parking spaces is 10–20 lx. The whole level of the illumination is lower and should be improved. The lighting design of this underground parking is suitable to use hybrid lighting system with light pipe and artificial light sources.

* Corresponding author. Tel.: +86 411 86323261.
E-mail address: gycao@dlpu.edu.cn (G. Cao).

http://dx.doi.org/10.1016/j.ijleo.2015.10.189
0030-4026/

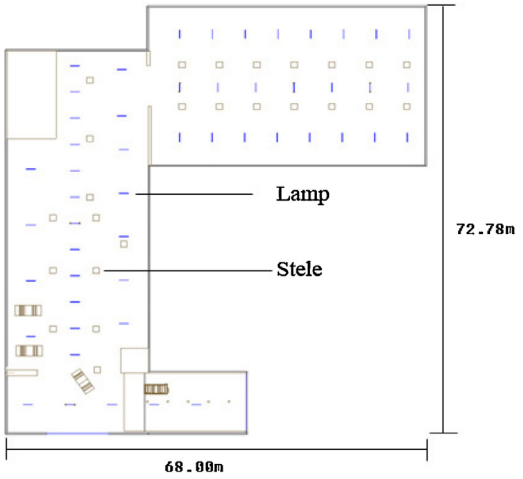

Fig. 1. The actual lamp arrangement.

3. Hybrid lighting system

Daylight is part of our lives. For its use, people think that daylight will bring more heat than artificial light. However, experiments show that the heat of daylight is much less than artificial for the same illumination [2]. Therefore, when daylight is used as a light source, it will significantly reduce the energy consumption of building. Furthermore, daylight also has the characteristics of clean, energy-saving and environmental protection [3]. Therefore, the hybrid lighting system with daylight and artificial light source was designed for the lighting of the underground parking in order to achieve energy saving and protect the environment.

Hybrid lighting system is composed of optical lighting system and artificial light sources. The tubular daylighting device is used to guide daylight in the optical lighting system [4]. LED is selected as artificial light source. System chart is shown in Fig. 2.

3.1. Tubular daylighting device

Tubular daylighting device is consists of optical collector, light pipe and diffuse device [5]. The principle of tubular daylighting device is that the optical collector collects a lot of natural light and the light passes through light pipe, in which the light will be multiple reflected in order to change the daylight spread direction [6]. The light arrives diffuse device at the bottom which brings uniform light indoor.

Light distribution curve represents the distribution in space of a lamp or light emitted and plays an important role in application and the lighting design [7]. Since we cannot measure the light distribution curve of tubular daylighting device by the traditional instrument, we use optical software to simulation its light distribution [8]. Therefore, tubular daylighting device is constructed by the software of Tracepro. Then the light distribution curve is imported into DIAlux for the lighting design of the underground

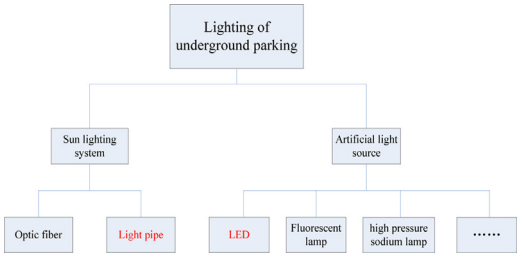

Fig. 2. Hybrid lighting system.

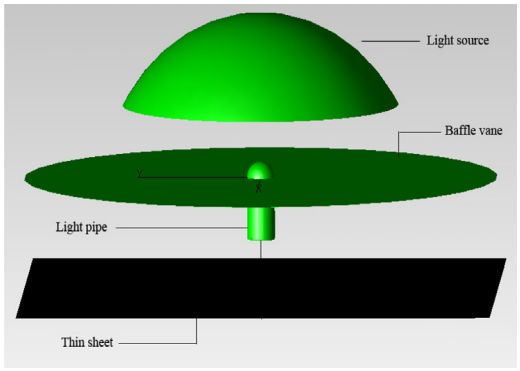

Fig. 3. The system model of light pipe.

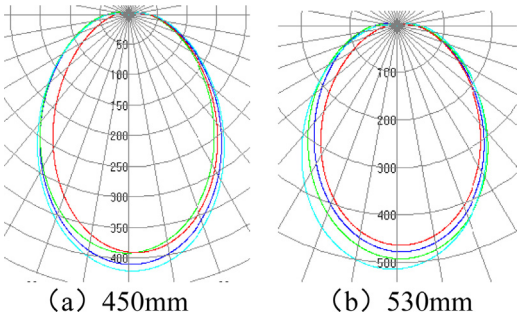

Fig. 4. Light distribution curves of 450 and 530 tubular daylighting devices.

parking. The system model was shown in Fig. 3. Tubular daylighting device includes optical collector, light pipe, Fresnel lens, light source, baffle vane and thin sheet. The diameters of light pipes have 250 mm, 330 mm, 450 mm, 530 mm, 750 mm. We choose 450 mm and 530 mm in the lighting design. The light distribution curves of 450 and 530 tubular daylighting devices are shown in Fig. 4(a) and (b), respectively. The light distribution curve of tubular daylighting device is nearly Lambertian distribution. The maximum intensity of 450 mm and 530 mm diameter are 400 cd and 500 cd respectively.

3.2. Artificial light source with LEDs

The illumination of the underground parking was changed with different daytime and weather. Therefore, the artificial light was used for supplement lighting when the internal illumination was less than the minimum illumination value. The LEDs were chosen as the artificial light sources. LEDs have many advantages, such as small power consumption, high luminous efficiency and friendly environment.

We choose 20 W LED lamp of Philip. Specific model: SSL eW Profile Powercore BCX411 997 mm 4 × 5-LED-HB/NW-4000. The luminous flux of LED is 720 lm.

4. Lighting design of the underground parking

4.1. Lighting design standards

At present, there are some specifications for lighting design of underground parking. The illumination standard of underground parking is 75 lx in the Architectural Lighting Design Standards (GB50034-2004) of China [9]. But this standard does not mentioned the region. In other Under Architectural Lighting Design Standard (CECS45:92), The low, medium and high illumination standards of the carriageway of underground parking are 30 lx, 50 lx, 75 lx and