

Analysis on Energy-saving Lighting Design of the Underground Construction

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ABSTRACT There are often no windows and lack of natural light in the most of underground space, so lighting design is the most basic for most underground architectural design. Natural lighting is not only for comfortable indoor energy-saving and healthy light environment, but also for the good indoor environment. We need to use natural light and artificial lighting conduction system to offset the lack of natural light and improve the effect of underground space of natural light.

KEYWORDS

Underground construction
Energy-saving
Natural light
Conduction system
Artificial illumination

1. Introduction

No windows and the lack of natural light most of the disadvantages of underground space, the lighting design of underground construction for most designs is very important.

2. Underground architectural lighting design problem to be solved

2.1. Lack of natural light

Irradiated enclosed underground spaces lacking natural light, and were mainly fluorescent lighting, underground space so monotonous and lack of change. To change these shortcomings, we need to color artificial light, light intensity, light in the direction of well-designed, or use artificial means to import natural light.

2.2. Adverse psychological reactions

Poor people a sense of direction in the underground space. People in the underground space changes in the direction and strength often depends on the room light to determine the position, incorrect visual information will distort people's disorientation, loss of directional sense in the

room, tend to make people feel uncomfortable. The well-lit interior, it can make up for the negative association of the dark.

3. Daylighting

In order to save energy and improve underground and windowless building indoor light environment, underground building, we should provide as much as possible through the side windows, skylights and natural light in the atrium of the building, but the underground space, mostly enclosed space, so we have to look for Some new underground architectural lighting methods. Natural light not only to meet the illumination requirements and energy saving lighting, more importantly, meet people on natural sunlight, the sense of space orientation, alternating day and night and other natural information perception psychological requirements. In addition, the underground construction in the form of natural lighting make the space more open and improve the ventilation effect to some extent, but in greatly reduced visual psychologically closed underground space, depression, and other adverse effects ghastly. Therefore, we can say, underground construction of natural lighting for underground construction has the effect of improving many aspects.

In recent years there have been some new underground architectural lighting methods. Although this type of construction method using natural lighting for people who have been studied, but there are many technical problems to be studied and solved. Our development of this method, the difference with the traditional lighting of the advantages of the process of lighting, daylighting systems (including heliostat, a condenser lens and light pipe, etc.) composition, technical value and prospects for economic develop-

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ment of a more comprehensive study.

Active solar systems. In many cases, underground space is completely isolated, and therefore unable to take advantage of natural light side windows and skylights adoption, active solar systems need natural light to pass through the tunnel, conduit, fiber, etc. to isolate the underground space. The basic principle of active solar system is calculated based on the change of the season, the time position of the sun using heliostat tracking system as a sun collector, and use high-efficiency light guide system deep underground natural light into the space. Here are two forms of the light guide system [1].

(1) Fiber optic catheter system. Lighting in the energy and environmental pollution severity, it has attracted people's attention, but the key to solving the problem is to promote green lighting technology. Light pipe is a new and effective use of natural light illumination device for nearly 20 years to develop. Underground space design, it can redistribute the natural light transmitted from the ground to the underground, in order to achieve certain lighting effects. It is not only saving energy, clean pollution-free advantages, but also to avoid some of the use of natural light in the system due to directly heat discomfort glare and potential problems exist in the sunlight.

The light guide illumination system is a new lighting system, mainly by the dome, the light pipe and diffuser of three parts. Its system principle is at the top of the dome and efficient collection of natural light into the system of internal re-allocation, and then after the light guide and strengthen transmission specially crafted, light pipe inner wall a highly reflective material, the reflectivity is generally above 95%, the light guide can rotating bending overlapping to change the angle and length of the light guide. Finally, the bottom of the system by the diffusing means of the natural light uniformly and efficiently irradiate light to wherever needed, and can avoid glare phenomenon. To obtain special lighting effects brought about by the natural light, breaking the lighting entirely rely on the power of ideas, it is a green, health, environmental protection, non-energy lighting.

From the way the lighting classification, light pipe has two active and passive. Active is to be able to track the sun collected by a solar concentrator, this type of light pipe collecting sunlight works well, but the cost of expensive concentrator, is rarely used in buildings. Currently the most used is passive lighting light pipe, connection poly mask and the light guide itself together fixed and poly mask and more from PC or PMMA injection from the surface condenser triangular total reflection prism. Daytime light guide can be achieved complete or partial use of natural lighting, thus saving energy.

Natural lighting can save energy consumption, applications in underground buildings will increasingly apparent. Light pipe technology to transport sunlight down to the ground floor, but do not produce too much heat. With the

improvement of people's living standards, and building energy saving urgency, light pipe technology will be widely used in China.

China is currently in the development and applications of the light pipe is still very backward, we do not have large-scale production capacity of the light pipe. The main reason is the high reflectivity of the light guide film used has not mastered its production process, the transmission efficiency of the light pipe to be further improved, in terms of basic research and product design, practical operation, etc. is not enough, therefore, Our light pipe technology has no large-scale enter the market.

(2) Heliostats. Heliostat is a reflection of the sun positioning device, by tracking the sun, it can accurately reflect sunlight to a fixed position, since this characteristic, it has been very good in terms of natural lighting of underground space Applications. With a parabolic mirror heliostats and mirrors will collect sunlight into the interior through the light guide optical design, to solve the shallow underground or windowless building lighting problem is more appropriate.

It is provided above the heliostat mirror. Tingri mirror sunflower follow the sun, but not exactly like a sunflower as "facing" the sun, but the sun refracted to the top of the reflective mirror heliostats, so the sun is actively collecting over, the mirror down, the sun is "transported" to the underground space.

Introduction of active natural light guide system, active way to collect sunlight, convert sunlight into interior lighting. Compared with the direct introduction of the glass window with an ordinary way sunlight, natural active not only improves the light guide illumination system, extending the time natural lighting indoor lighting, and the scattering of light were to prevent the generation of glare, improve the illumination uniformity, more comfortable lighting effects.

Active light guide system through the collection, reflection, transmission, scattering, etc., will be introduced into the indoor sunlight. The light guide system consists of three parts, including heliostat, plane mirror and five groups "skylight + diffusion plate". In addition heliostats, the other components are stationary. Among them, the role of the heliostat is to collect sunlight. Heliostats need to be constantly adjusted to change the angle position of the sun in order to ensure heliostat light collected and reflected off a plane mirror all been received. Planar mirror heliostats receiving collect sunlight and reflect it into the skylight. Become more uniform light for indoor lighting from skylights scattering of incident light through the diffusion plate.

Heliostat solar light is the key to accurately track the success of the system, for accurate calculation of the sun at various times of the position, and convert it to the heliostat attitude adjustment data to ensure an accurate reflection of sunlight onto the plane mirror.

In addition to accurate heliostats track the sun, also called the outgoing light has condensing effect, therefore, the use of toroidal things to type a heliostat mirror, rather than ordinary spherical mirror type, the former can be effectively reduced the optical system aberration, a more focused light rays converge in a small area.

4. Artificial lighting

Underground construction is difficult to entirely rely on natural light, even if by natural light, it is difficult to make the natural light to reach the interior space of the building. Therefore, in the natural light cannot reach the exact underground space, natural light, artificial lighting as a supplement is essential. In the indoor artificial lighting design should consider illumination, uniformity, color of suitability and psychological effects of having a visual art light environment, the overall consideration to determine the tone and light fixture selection, and strive to create a suitable human visual characteristics lighting conditions [2].

4.1. Principles underground construction of artificial lighting

(1) It should be based on the use of underground engineering, space and architectural forms, materials, finishes, colors and lighting in the form of comprehensive consideration.

(2) Illuminance should meet the job requirements.

(3) Alone should reduce cold white fluorescent light, so mix various light sources in order to reduce the extent of monotonous light color.

(4) In the entrance, because it plays a role in connecting inside and outside, with respect to the internal lighting should have a higher degree. From the outside into the underground interior illumination decreases, we should maintain a suitable gradient.

4.2. Artificial Lighting Design

4.2.1. Create artificial light with a natural characteristic of artificial lighting with light stronger than the sun disadvantage small and light color insufficiency

Therefore, the design of artificial light to simulate natural light feature is an important way. The system can simulate sunlight and artificial light color, stability, and in the direction Change in intensity. Full spectrum bulbs simulate natural light, ultraviolet radiation may be provided to facilitate the physical health of people in the underground space. The full spectrum light bulb hidden indirect lighting, or as to fake skylight above, it will make people mistakenly thought it was daylight lighting. Designers should windowless underground space manipulation and artificial light to simulate sunlight in the day regular changes, the specific approach is based on cyclical changes in the sun outside the day to change the color and intensity of artificial light.

4.2.2. Changing lighting for lighting design, the use of light changing role

It is important, this is not simply to change, but to strengthen the limited space for different functions through change and reflect the different functional spaces. You can also increase the space along the main purpose of the aisle illumination light to guide people to the sport. The creation of a similar nature with artificial light, changing light makes the space richer, more dynamic.

5. Daylighting and energy

Save energy, protect the environment, improve the lighting quality is the purpose of the green lighting, in today's increasingly tense energy, full use of natural light, sunlight through optical waveguide system transmitted directly to the interior lighting where needed, especially in some underground or windowless building, must be a good way to future utilization of solar energy, more conducive to the achievement of sustainable development strategy.

5.1. Light guiding system in energy saving methods

The use of light guide light pipe lighting method; optical fiber light guide lighting method; prism light transmitting lighting method; photovoltaic effect of indirect lighting illumination method. But no matter what methods are designed to reduce costs and improve efficiency, in order to obtain an energy-efficient, economical lighting technology in improving underground space environment. Light guide means is underground lighting system essential part. Select the appropriate light guide way, it is key to the design. Quartz glass optical waveguide having a high transmission, good flexibility and ease of installation, etc., is an ideal photoconductive material. Currently, this is limited to the application of optical fiber communications, and because of lower production capacity, market demand is not, so the price is particularly expensive. If you use a lens, a mirror composed of geometric optical light guide system, then the purchase of a large number of funds spent on the optical element is considerable. By contrast, the choice of a hollow light pipe is economical and practical, the hollow light pipe easy processing and easy installation features, the inner wall coating material having a high reflectivity, the same can obtain a higher transfer rate and lumen utilization. Therefore, there is a certain value. So you should choose a suitable photoconductive material, to achieve energy efficiency standards, the maximum limit degree of utilization of the sun.

China is currently using the existing light guide lighting engineering practice in the underground space, receive better energy efficiency, such as the Olympic central area of Beijing underground garage used light pipe system. The project installed 19 sets of light pipe systems, a single set of light pipe system may provide illumination for 70 m² garage. Light pipe inner diameter of 1.2 m, a length of the light guide tube 3.35 m and 3.85 m. According to standard

garage ground illumination 75 lx, engineering design calculations in accordance with lighting effects simulation and control design complete light pipe systems engineering, after completion of the measurement, cloudy day when the whole outdoor illumination when converted into 2,000 lx, indoor average illumination of 75 lx, meet the standards. When outdoor illumination reaches 95,551 lx, indoor illumination reaches 670 lx. In energy efficiency, 19 sets of light pipe system for the garage annual saving 24,472 kW/h electricity.

5.2. Artificial lighting energy method

In the underground space, maximum use of natural light cannot fully meet the requirements, at night and on cloudy days need the help of artificial means to assist illuminator. In order to save power consumption and meet environmental and efficiency standards, underground space use LED intelligent light, the same can achieve energy saving and environmental protection standards [3].

LED intelligent lighting to provide appropriate lighting in accordance with actual needs, without compromising the quality of the premise of illumination, a significant reduction in power consumption. It has many advantages:

(1) Low power consumption. LED power consumption is very low, DC drive, ultra-low power consumption (single tube 0.03-0.06 W), electro-optical power conversion close to 100%. LED's operating voltage is generally 2-3.6 V, the operating current is 0.02-0.03 A. That said, it does not exceed power consumption 0.1 W, the same lighting effects than traditional energy sources more than 80%.

(2) Long service life. Some have called for longevity lamp LED light source, it is a solid cold light source, epoxy resin, light body and no loose parts, there is no filament light easy to burn, heat deposition, the light fades and other shortcomings, at the right current and voltage, life of up to 60,000 to 100,000 h, longer life than conventional light

sources more than 10 times.

(3) High-brightness, low-calorie. LED using luminescence technology, much lower heat than conventional lighting.

(4) Environmental protection. LED is made from non-toxic materials, unlike fluorescent lamps containing mercury can cause pollution, while LED can also be recycled. No ultraviolet and infrared spectra, neither heat nor radiation, glare is small, cold light source, safe touch, typical of green lighting.

6. Conclusion

In the underground building, natural phototherapy should be provided whenever possible; at the same time also designed artificial light system to simulate the characteristics of natural light. Space should have enough illumination to meet the functional and practical requirements; in addition, lighting design should be able to strengthen the sense of space, spacious and create a vibrant, diverse underground building interior environment.

Conflicts of interest

These authors have no conflicts of interest to declare.

Authors' contributions

These authors contributed equally to this work.

References

1. Li, Y. X., Li, S. T., & Ni, W. Y. (2009) Heliostat technology research and application. *China Science and Technology Information*, 24, 26-27.
2. Wang, W. Q. (2000). Urban underground space planning and design. *Nanjing: Southeast University Press*.
3. Tong, L. X. (2005). Underground space and modern urban development. *Beijing: China Building Industry Press*.